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PRINCIPAL INVESTIGATOR: Roger P. Hamernik, Ph.D.

CONTRACTING ORGANIZATION: Plattsburgh State University of New York
Auditory Research Laboratories
Plattsburgh, New York 12901

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Roger P. Hamernik, Ph.D.

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Plattsburgh State University of New York
Auditory Research Laboratories
Plattsburgh, New York 12901

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13. ABSTRACT *(Maximum 200 words)*

This research is directed at studying the effects on the auditory system of exposure to high levels of reverberant impulse noise using an animal (chinchilla) model. The blast waves were generated by a three inch diameter shock tube (source III), which produced wave signatures having spectral energy concentrated in the 1-2 kHz region. The waves were discharged into a reverberant chamber within which animals were individually exposed. Animals were exposed to either 150, 155 or 160 dB peak SPL impulses. The number of impulses presented at each intensity was 1, 10 or 100, with repetition rates fixed at 1 impulse/sec. This parametric design yielded 9 groups of animals. There were 15 animals in each group. Brainstem evoked potentials were used to estimate temporary and permanent threshold shifts and conventional surface preparations of the cochlea were used to quantitatively assess sensory cell loss. This midterm report presents the audiometric data and a portion of the histological data for the 136 animals that completed the exposure protocol. The audiometric and available histological data showed that damage to the auditory system systematically increased as the energy of the exposure was increased through manipulation of number of presentations or peak SPL.

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FOREWORD

Opinions, interpretations, conclusions and recommendations are those of the authors and are not necessarily endorsed by the U.S. Army.

Citations of commercial organizations and trade names in this report do not constitute an official Department of the Army endorsement or approval of the products or services of these organizations.

In conducting research using animals, the investigators adhered to the "Guide for the Care and Use of Laboratory Animals," prepared by the Committee on Care and Use of Laboratory Animals of the Institute of Laboratory Animal Resources, National Research Council (NIH Publication No. 86-23, Revised 1985).

P.I. Signature — Date: 9 June 93

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I. Introduction: There are a number of different suggested standards for exposure to impulse/impact noise, e.g. Coles, et al. (1968), OSHA, (1974), Smoorenburg (1982), and Pfander et al., (1980). Although each of these criteria has its proponents, none of them are in complete agreement with the existing data (Smoorenburg, 1990). Unfortunately, there is an extremely limited empirical data base upon which a new standard can be built. What is needed is a new criterion based upon a cohesive, systematically acquired body of experimental data. The need for such a data base has been emphasized by e.g., von Gierke (1978, 1983); Ward (1983); and the NATO Study Group RSG.6 (1987) and most recently by the NRC-CHABA Working Group (1992). In particular, two areas of the existing data base that have been singled out as being deficient in data are those relating to the effects of high level reverberant impulse noise exposure, and the effects of the impulse energy spectrum. While data on spectral effects have recently begun to accumulate, [see e.g., Price 1979, 1983, 1986; Patterson et al., 1986, 1990; Patterson and Hamernik, 1990; and Hamernik et al., 1990] there is virtually no information available on reverberant blast wave exposure. The difficulties associated with generating such a data base are compounded by the extremely broad range of high intensity noise transients that exist in various industrial and military environments. For example, in industry reverberant impacts with variable peak intensities, usually under approximately 140 dB, often occur. At the other extreme, the diversity of military weapon systems produce impulses which originate as the result of a process of shock wave formation and propagation following an explosive release of energy. These waves, which can have peak levels well in excess of 180 dB, can be either reverberant or non-reverberant in nature depending upon the environment in which they are encountered. Trying to develop a single standard to cover this broad range of "acoustic" signals is a formidable task.

Several laboratory and epidemiologic studies indicate the potential severity and complexity of the problem. For example, Hynson et al., (1976) showed that a free field impulse which is followed by reflected components can contribute disproportionately to the eventual permanent threshold shift (PTS) and cochlear sensory cell loss. This study, however, was based upon a small number of animals (2 groups with 5 animals/group) and has not been replicated. More recently Roberto et al., (1989) reported on the anatomical changes in pigs and sheep exposed to high level reverberant blast waves within an armored

vehicle. Although no measurements of hearing were made, the lesions in the cochlea and middle ear were extensive and probably the result of direct blast wave-induced, mechanical damage to the cochlea (Luz and Hodge, 1971). The levels, while extremely high (approximately 195 dB), were typical for the type of projectile impact and nature of the armored vehicle. Although not a hearing study, Clemedson and Jonsson (1976) indicate that exposures to reverberant blast waves are more hazardous to the respiratory system than are exposures to the same type of stimulus in a non-reverberant system. Since the total energy of the exposure is increased and under certain circumstances peak levels are also increased, this result, showing an exacerbation of effect in a reverberant system is not surprising and will most likely also be true for hearing trauma. Demographic data such as that of Walden et al., (1971, 1975) can be interpreted as indicative of an increased risk of hearing loss when personnel are exposed to high noise levels in acoustically hard (reverberant) environments. Additional, but much more circumstantial evidence emphasizing the potential for trauma from reverberant impulses can be found in clinical reports, such as Salmivalli (1967) or Smyth (1974). These reports document the severe hearing loss following acute acoustic trauma from a variety of military and non-military sources. While there is little or no documentation of the acoustic signal, one can assume, with some confidence, from the circumstances of the trauma, that the signal was reverberant.

The energy spectrum of an impulse is also widely acknowledged to be important in risk assessment, although relatively little experimental data is available that can be used to understand the role of spectrum in the production of hearing loss. In fact, one of the surprising features of the existing or proposed impulse noise exposure criteria is the general lack of specific consideration that is given to the frequency domain representation of the impulse, a point frequently raised by Price (1979) and others. Some deference is, however, given to the spectrum in these criteria, but in a covert or indirect manner (e.g., through the use of A-weighting of the stimulus or through the handling of the A and B duration variables). A more direct spectral approach to the evaluation of impulses and impacts was proposed by Kryter (1970). His suggestions, while based upon sound reasoning, never really caught on. The Kryter approach appeared attractive in its ability to predict the amount of temporary threshold shift measured two minutes after exposure (TTS_2) to a noise transient, provided that the TTS_2 was

not very large or alternatively that the levels of the transient in any given frequency band were not excessive. Price (1979, 1983, 1986), to some extent has tried to build upon and extend the Kryter approach by considering the spectral transmission characteristics of the peripheral auditory system. Price's reasoning led to the following conclusions: (1) There is a species specific frequency, f_o, at which the cochlea is most vulnerable and that impulses whose spectrum peaks at f_o will be most damaging. This would appear to be true, according to Price, regardless of the distribution of energy above and below f_o. For humans the suggested frequency is 3.0 kHz. (2) Relative to the threshold for damage at f_o, the threshold for damage should rise at 6 dB/octave for $f_p<f_o$ and at 18 dB/octave for $f_p>f_o$, where f_p = spectral peak of the impulse. In subsequent studies Price (1983, 1986) tried to relate, with varying degrees of success, experimental data obtained from the cat to the predictions of his model. The data reported by Price are limited, and suffer from a large variability which because of the small number of subjects in the various exposure groups makes general conclusions very tentative. While his data do reinforce his predictions concerning the effect of spectral characteristics, there are a number of issues related to the presentation of threshold data and the limited histological data that limit their use in the quantitative development of exposure standards. More recently, Hamernik et al. (1990), Patterson and Hamernik (1990) and Patterson et al. (1993) have reported on an extensive series of parametric studies in which the spectra of non-reverberant impulses were varied. A review of the literature indicates that, except for the studies mentioned above, there are few, if any, other published results obtained from experiments specifically designed to study the effects of the spectrum of an impulse on hearing trauma.

The Patterson and Hamernik, (1990), Hamernik et al. (1990) and Patterson et al. (1993) reports on the results of exposures to several types of impulse noise and blast waves represent one of the most extensive compilations of data on spectral effects. These studies have shown that it is possible to bring order to relations among permanent threshold shifts produced by exposure to impulsive noise and the spectrally weighted energy of the exposure. What was encouraging about these data was that an empirical weighting function obtained using impulses that were generated by conventional electro-acoustic methods could be used to unify the results obtained using high-level shock tube generated blast waves. These results were also in general qualitative

agreement with the predictions of Price. This interim report documents the results of exposures to reverberant impulses having peak SPLs in the range 150 to 160 dB.

II. Methods: The basic experimental protocol that is common to all of the experiments reported here, consists of the following steps: (1) Preexposure tympanograms and audiograms are measured on each animal. (2) The animals are exposed to noise under well-controlled conditions. The temporal and spectral characteristics of the noise are recorded. (3) The animal's evoked response thresholds and tympanograms are again measured immediately after exposure and thresholds are measured at regular intervals after exposure. At 30 days postexposure, the audiogram is again measured to establish the animal's permanent threshold shift. (4) The animals are euthanatized and their cochleas are then prepared for microscopic analysis. Cochleograms, which provide a quantitative description of the extent and location of the hair cell lesions, are prepared for each cochlea. Additional experimental details can be found in previous contractor reports (Hamernik et al., ADA 203-854, ADA 206-180 and ADA 221-731).

(a) Subjects: The chinchilla was used as the experimental animal. Over the years, the chinchilla has been used in a wide variety of auditory experiments and consequently, much is known about its threshold (Miller, 1970; Henderson et al., 1983), psychophysical tuning curves (McGee et al., 1976; Salvi et al., 1982a), threshold for gap detection (Giraudi et al., 1980) and amplitude modulated noise (Salvi et al., 1982b). These psychophysical results indicate that the chinchilla's hearing capabilities are quite similar to those of man. The chinchilla is perhaps the most common animal used in noise trauma research even though there is a general consensus that the species is more susceptible to noise trauma than is man (Trahiotis, 1976). However, phenomenologically the chinchilla is considered to be a suitable model for man. Thus, the chinchilla was chosen as a reasonable animal model for the blast wave studies reported in this document.

To date, one hundred and thirty-six (136) chinchillas have completed the experimental protocol. Each animal was anesthetized [IM injection of Telazol® (40 mg/kg], and made monaural by the surgical destruction of the left cochlea. The monauralization allows for the testing of hearing function in a single ear. During this surgical procedure, a chronic electrode was implanted near the inferior colliculus for single-ended, near-field recording

of the evoked potential (Henderson et al., 1973; Salvi et al., 1982a). The animals were allowed to recover for at least a week before evoked potential testing began.

(b) <u>Preexposure testing</u>: Hearing thresholds were estimated on each animal using the auditory evoked potential (AEP). The AEP has been shown to be a valid index of hearing threshold in the chinchilla. The correlation between the behavioral and evoked response measures has been strengthened by directly comparing, in the same animal, estimates of noise-induced behavioral and evoked potential threshold shifts (Henderson et al., 1983; Davis and Ferraro, 1984). There is a close correlation between the behavioral and evoked potential thresholds before, during, and after acoustic overstimulation. In other words, the AEP threshold estimation procedure provides a good estimate of the magnitude of noise-induced hearing loss. The animals were awake during AEP testing and restrained in a yoke-like apparatus to maintain the animal's head in a constant position within the calibrated sound field. AEP's were collected to 20 msec tone bursts (5 msec rise/fall time) presented at a rate of 10 per second. A general-purpose computer (Digital Equipment Corporation MicroPDP-11/73) with 12-bit A/D converter (Data Translation 3362), timer (ADAC 1601) and digital interface (ADAC 1632) was used to acquire the evoked potential data and control the frequency, intensity and timing of the stimulus via a programmable oscillator (Wavetek 5100), programmable attenuator (Spectrum Scientific MAT) and electronic switch (Coulbourn Instruments S84-04). The electrical signal from the implanted electrode was amplified (50,000x) and filtered (30 Hz to 3000 Hz) by a Grass P511J biological amplifier and led to the input of the A/D converter where it was sampled at 20 kHz (50 msec period) over 500 points to obtain a 25 msec sampling window. Each sampled waveform was analyzed for large amplitude artifacts and, if present, the sample was rejected from the average and another sample taken. Averaged AEP's were obtained from 250 presentations of the 20 msec signal. Each waveform was stored on disk for later analysis. A schematic of the AEP laboratory and the main laboratory computer system with which the AEP system interacts is shown in Figures 1 and 2.

Thresholds were measured using an intensity series of test tones having 5 dB steps at octave intervals from 0.5 to 16.0 kHz and at the half-octave frequency of 11.2 kHz. Threshold was determined to be one half step size (2.5 dB) below the lowest intensity that showed a "response" consistent with the

responses seen at higher intensities. The average of at least three separate threshold determinations at each frequency obtained on different days was used to obtain the preexposure audiogram.

(c) Middle ear function: In order to be certain that the blast waves have not altered middle ear function and thus indirectly contributed to threshold changes or to a protective effect for subsequent impulses, tympanometric functions were measured just prior to exposure and immediately following exposure. A Grason-Stadler 1723 Middle Ear Analyser was used to obtain tympanograms at 220 and 660 Hz. The tympanogram indicates perforations, disarticulations, severe edema, etc. The specific methodology and some experimental details can be found in Eames, et al. (1975).

(d) Blast wave generation, measurement and analysis: Shock waves were generated by a 3-inch diameter (Lamont) shock tube utilizing a quick acting valve to initiate the pressure distrubances. This source (hereafter refered to as source III) is described in greater detail in the following contractor reports: Hamernik et al., ADA 203-854; 206-180 and 221-731.

A cross-sectional view of the "Lamont" driver is shown in Figure 3. The 3-inch Lamont shock tube source is shown schematically in Figure 4. The Lamont source uses a relatively simple rapid acting valve to quickly establish a high pressure discontinuity in the expansion section in order to "drive" the shock front. A force differential generated over the area of the low pressure chamber relative to the high pressure chamber, on the rear plate, maintains the seal of the high pressure chamber. As the low pressure is gradually reduced, a point is reached where the net force acting on the valve reverses direction and the valve rapidly thrusts forward releasing the "slug" of high pressure gas into the expansion section. N_2 was used as the operating gas. The pressure in the high pressure chamber was varied from approximately 100 psig to 1000 psig to achieve peak sound pressure levels of the blast wave of from 150 dB to in excess of 160 dB at the exposure location. The peak SPL of the blast wave was controlled by systematically adjusting the pressure in the compression section. The pressure-time history of the blast wave was recorded using a transducer located on the center line of the outlet of the shock tube at the location of the test animal.

In order to produce reverberant conditions, a hard-walled three-foot "spherical" reverberant chamber was built. The reverberant chamber was built in the approximate shape of a dodecahedron from joined segments of 1/4 inch

thick aluminum plate. The reverberant chamber was constructed in a manner that allows the rear one-third of the chamber to be opened. The chamber was fitted with a mounting platform that allows the awake and restrained animal to be fixed with its head in the geometric center of the chamber with the experimental ear facing the source (i.e., normal incidence). The center of the free standing reverberant chamber (i.e., not connected to the shock tube) was positioned 29 to 48 inches from the shock tube exit depending upon the desired peak SPL and approximately 30° off the center line of the tube as shown schematically in Figure 4. An instrumentation port on the side of the chamber allowed calibration to be performed as described in the next section.

(e) Calibration of the chamber: The computer system used in the calibration was a Compaq 286 Deskpro personal computer using the ASYST™ application package (ASYST™ Software Technologies, Inc., Rochester, NY). A schematic of our current instrumentation set up is shown in Figure 5. The blast wave was first digitized and then recorded in storage devices (e.g., hard disk or magnetic tape). By using the customized software developed in our laboratory, each digitized blast wave was analyzed to extract information such as the total "acoustic energy" (time integrated pressure squared), energy spectrum, peak and root-mean-square (RMS) sound pressure level (SPL), etc.

Two different types of transducers were used to convert the dynamic acoustic pressure into an electrical signal. The B&K 1/8 inch microphone (Type 4138) and the PCB crystal microphone (Model 112A22) were selected because of their ability to record high peak levels and their relatively fast rise times. A B&K microphone preamplifier (Type 2639), a B&K measuring amplifier (Type 2606), and a PCB six-channel amplifying power unit (Model 483A08) were used to amplify the analog signals from the B&K and PCB microphones respectively. Both transducers yielded identical results. Since the PCB transducers are more rugged and much less expensive, they were used for routine calibration. Performance and calibration of the PCB's, however, was regularly checked with the B&K measurement system. The B&K system was calibrated using a B & K pistonphone and a high pressure calibrator (Model 4221). The amplified analog signals were monitored on an oscilloscope. The output signal from the transducer was amplified and, in order to avoid aliasing problems that can occur in analog-to-digital (A/D) conversion, the amplified signals were filtered using an anti-aliasing filter prior to digitizing. The sampling rate of the A/D converter (12-bit) was set at 500

kHz and the cut off frequency of the anti-aliasing filter was set at 150 kHz (approximately 1/3 of the sampling rate). For each blast wave, 16,384 samples were recorded for later analysis. Software was written using this PC-based system to perform the following tasks: total sound exposure and exposure level calculations (Young, 1970), energy flux calculations, and spectral analysis using a 4096-point FFT, A-weighted analysis, etc. Thus, for each impact the total sound exposure or exposure level could be calculated (i.e., the time integrated, squared sound pressure). During each exposure a PCB microphone was mounted near the external canal of each experimental animal during exposure to document each stimulus presentation.

(f) Exposure of animals: For a given exposure condition (Table I), each chinchilla was exposed at the same calibrated location of the reverberant chamber. During exposure the animal was unanesthetized but immobilized in a leather harness (Patterson et al., 1986). The right pinna was folded back and fixed in place to insure that the entrance of the external meatus was not obstructed and the position of the entire animal was adjusted so that the cross sectional plane of the external meatus was oriented parallel to the advancing shock front (i.e., a normal incidence). Each experimental group consisted of fifteen (15) animals. Each animal was individually exposed to one of the following exposure conditions: 150, 155 or 160 dB peak SPL; 1, 10, or 100 impulses presented at the rate of 1/min. This combination of one source, three intensities and three numbers yielded a total of 136 animals distributed in 9 groups to complete the experimental protocol for the three-inch Lamont blast wave source. The interstimulus internal (ISI) was fixed at the rate of 1/min for two reasons, (1) our previous results indicate that exposure paradigms with ISI's in the range 10/min through 1/10min do not in general produce systematic statistically significant different results, and (2) to attempt to minimize the number of animals and time expenditure by focusing first on the most important variables of peak level and number. An ISI of 1/m was chosen because it represents a reasonable approximation to many situations encountered in practice.

(g) Postexposure testing: After the exposure was completed, threshold recovery functions were measured at 0.5, 2.0 and 8.0 kHz at 0, 2, 8, 24 and 240 hours after removal from the noise (using the same method as described for preexposure testing). After at least 30 days, final audiograms were constructed using the average of three separate threshold determinations at

each of the seven preexposure frequencies. Permanent threshold shift was defined as the difference between the postexposure and preexposure thresholds at each individual test frequency.

(h) Cochlear histology: Following postexposure audiometric testing, the animals were euthanatized by decapitation and the cochleas were immediately removed and fixed. The cochleas were dissected and the status of the sensory cell population was evaluated using conventional surface preparation histology (Engstrom et al., 1966). Briefly, the stapes was removed and the round window membrane opened to allow transcochlear perfusion, via the scala tympani/scala vestibuli with cold 2.5% glutaraldehyde in veronal acetate buffer at 7.3 pH (605 mOsm). Postfixation was performed on the following day with one percent osmium tetroxide in veronal acetate buffer (pH 7.3) for 30 minutes. The cochleas were then dissected and the entire sensory epithelium along with the lateral wall structures were mounted in glycerin on glass slides. The status of sensory and supporting cells were evaluated with Nomarski Differential Interference Contrast microscopy and entered into a data base on a laboratory computer (Digital Equipment Corporation MicroPDP-11/73 and Macintosh II). Standard cochleograms were then constructed by computing the percent sensory cell loss across the length of the cochlea in 0.24 mm steps. These cell loss figures were then converted into percent loss over octave bands centered at the audiometric test frequencies along the length of the cochlea and correlated with the frequency-place map constructed by Eldredge et al., (1981). A schematic of the morphometric system is shown in Figure 6. Quantitative histology of the cochlea, relating sensory cell populations to frequency specific locations on the basilar membrane, is considered as a necessary adjunct to audiometric measures when developing exposure standards. At the very least, histology provides an alternate measure of pathology which should correlate with functional measures. However, threshold measures represent only a single dimension of hearing. While traditionally considered to be the most basic measure, thresholds do not always reflect the extent of pathology (See e.g., Eldredge et al., 1973 or Hamernik et al., 1989).

(i) Statistical analysis: The descriptive analysis of the data from these experiments consisted of: (1) a complete description of raw data and group means and standard deviations; (2) a graphical representation of mean recovery curves; (3) tabular and graphical representation of individual histological summaries; and (4) group summaries of the histological analysis.

Further examination of the data employed mixed model analyses of variance with repeated measures on one factor (frequency) using the SPSS Release 4.0 statistical package. Unless otherswise noted, the probability of a Type I error was set at 0.05. An example of a complete data archive for a single experimental group is presented in the Appendix.

(j) Data archive: For each experimental animal and each experimental group, a complete data archive is maintained in the format shown in the Appendix for the 155 dB peak SPL; 1x exposure condition. From an appendix of this type all audiometric and histological data for each animal can be retrieved for future analysis. A complete archive of individual animal and group mean data will be submitted to the COR at the termination of this contract.

III. Results:

(a) The stimulus: Figure 7 illustrates each of the three impulses generated by source III that were used for the exposures described in this report, along with each of their frequency spectra. In the reverberant enclosure, peak pressure fluctuations over 120 dB persist for up to approximately 90 ms. Unweighted octave band energy values for each of the impulses are shown graphically in Figure 8. Energy values were computed from an expression of the form;

$$\int_0^T \frac{p^2(t)\,dt}{\rho C} \quad (J/m^2)$$

where ρC = 406 mks rayls. For each exposure, various weighted and unweighted energies; energy levels, and octave band values for each exposure are presented in Table I. [Note: P-weighted energies were obtained using the weighting funciton presented by Patterson et al., 1993.]

(b) Preexposure thresholds: The preexposure threshold means and standard deviations for each of the nine exposure groups are presented in Table III. The preexposure thresholds were analyzed for differences using a two-way mixed model analysis of variance with repeated measures on one factor (frequency). The analysis revealed a statistically significant main effect of frequency ($F = 325.21$, $df = 6/750$, $p < .05$) which was expected based upon our knowledge of the chinchilla audiogram (Fay, 1988). The main effect of experimental group was not statistically significant ($F = 0.88$, $df = 8/125$) nor was the interaction of group and frequency ($F = 1.36$, $df = 48/750$). Therefore, the

nine groups in this study did not significantly differ in mean thresholds for the audiometric frequencies tested before noise exposure.

The thresholds measured using the AEP are typically better than the behavioral thresholds published by Miller (1970) when a correction for the effects of temporal integration is applied (Henderson, 1969). The better thresholds probably reflect improvements in the methods currently used to obtain AEP thresholds.

(c) Postexposure thresholds: The group mean recovery of threshold over a 30-day period following each of the exposures is shown in Figure 9, 10 and 11. The following generalizations can be extracted from these figures: (1) Exposure to a single impulse between 150 and 160 dB peak SPL produces relatively little (< 25 dB) threshold shift (TS) immediately following exposure and thresholds at each of the three test frequencies recovered to normal within roughly 10 days following exposure. (2) As the number of impulse presentations increased to 10 and 100, there were large and systematic increases in TS. For the 10x exposure, TSs varied from around 40 dB to almost 70 dB. Although a ten-fold increase in the number of impulses produced large changes in TS, a 10 dB increase in the peak level produced relatively small (~ 10 dB) changes in the initial TS (TS_0). However, increasing the number of presentations to 100 impulses caused only about a 10 dB increase in TS_0 above the 10x condition, and when the peak level was increased from 150 dB to 160 dB for the 100x condition, there was little or no change in TS_0. (3) As both number of impulses increased and peak levels increased, there was a clear delay in the TS recovery process. TSs would recover very little, if at all, during the first 5 to 10-days postexposure. Such delayed recovery has been shown to correlate with a noise induced pathology (Hamernik et al., 1988). The above generalizations were true for all three test frequencies that were followed over the 30-day recovery period.

(d) Noise-induced permanent threshold shift: Figures 12 and 13 illustrate the group mean PTS for all groups exposed to reverberant blast waves from source III. Figure 12 shows the effect of number (N) of reverberant impacts at each of the three levels, while Figure 13 shows the effect of the peak SPL of the impacts at each of the three Ns. Two-way mixed model analyses of variance with repeated measures on one factor (frequency) were performed on the PTS measures depicted in each panel of these two figures. The analyses comparing number of impulses within each peak SPL level

of impulse (Figure 12) showed statistically significant main effects of number of impulses and frequency for all three analyses as well as statistically significant interactions between number and frequency. These results are clearly evident from an inspection of the mean data shown in Figure 12, i.e., there is a systematic increase of PTS across most audiometric test frequencies as the number of impulse presentations is increased. The statistically significant interaction suggests that the magnitude of the main effect of number of impulses is dependent on the frequency at which PTS is measured. This effect is most clearly seen in the 150 dB data panel at the higher test frequencies.

Another three analyses of variance were used to evaluate the effect of impulse level on groups of animals exposed to the same number of reverberant impulses (Figure 13). For the groups exposed to a single impulse, little PTS was observed and the analyses revealed that neither main effect was statistically significant. The main effect of peak was statistically significant for the groups exposed to 10 impulses ($F = 6.48$, $df = 2/41$, $p < .05$). The main effect of peak was not statistically significant for the groups exposed to 100 impulses ($F = 2.05$, $df = 2/43$), but the interaction of peak and frequency was statistically significant ($F = 4.21$, $df = 12/258$, $p < .05$). As with the data presented in Figure 12, the results of this statistical analysis can be clearly seen in the mean data presented in Figure 13.

(e) Histological results: To date, hair cell population data has been collected only from the three groups exposed to the 155 dB peak SPL impulses. The group mean percent inner and outer hair cell losses computed over octave band lengths of the cochlea are shown in Figure 14. As with the audiometric data, the histological results are systematic in showing a clear increase in the severity of noise-induced damage as the energy of the exposure increases. For the single presentation of the 155 dB impulse, there is generally no sensory cell loss. Increasing the number of presentations to 10, causes severe sensory cell loss in the 1.0 and 2.0 kHz octave band regions of the cochlea; a lesion generally in accord with the 1-2 kHz spectral peak in the distribution of energy of the impulse. A further increase in presentations to 100, causes an increment in damage at the 1-2 kHz region, but more significantly a substantial spread of damage to more apical and basal regions.

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Table I

Definition of Experimental Groups

Group	N	Peak SPL	Number of Impulses
1	15	150	1
2	15	150	10
3	15	150	100
4	15[1]	155	1
5	15	155	10
6	15	155	100
7	15	160	1
8	16[2]	160	10
9	15	160	100

1 Postexposure threshold and PTS at 11.2 kHz test frequency missing in one subject (# 1402) due to operator error.

2 Audiometric data missing in one subject (# 1571) due to loose AEP electrode.

Table II

Unweighted and weighted octave band energies for a

single reverberant impulse generated by Source III

150 dB peak SPL

Octave Band CF (kHz)	Unweighted (J/m^2)	A-energy (J/m^2)	P-energy (J/m^2)	Unweighted* (dB)	A-energy* (dB)	P-energy* (dB)
< 0.125	0.0137	0.0000		-18.6	-51.4	
0.125	0.0065	0.0002		-21.9	-38.0	
0.250	0.0023	0.0003	0.0000	-26.4	-35.0	-43.4
0.500	0.0113	0.0054	0.0007	-19.5	-22.7	-31.5
1.000	0.2329	0.2329	0.2329	-6.3	-6.3	-6.3
2.000	0.1548	0.2041	0.1548	-8.1	-6.9	-8.1
4.000	0.0707	0.0891	0.4463	-11.5	-10.5	-3.5
8.000	0.0392	0.0304	0.0392	-14.1	-15.2	-14.1
> 8.000	0.0205	0.0024		-16.9	-26.2	

155 dB peak SPL

Octave Band CF (kHz)	Unweighted (J/m^2)	A-energy (J/m^2)	P-energy (J/m^2)	Unweighted* (dB)	A-energy* (dB)	P-energy* (dB)
< 0.125	0.0677	0.0000		-11.7	-44.5	
0.125	0.0080	0.0002		-21.0	-37.1	
0.250	0.0067	0.0009	0.0001	-21.8	-30.4	-38.8
0.500	0.0371	0.0177	0.0023	-14.3	-17.5	-26.3
1.000	0.8382	0.8382	0.8382	-0.8	-0.8	-0.8
2.000	0.4631	0.6105	0.4631	-3.3	-2.1	-3.3
4.000	0.2128	0.2679	1.3427	-6.7	-5.7	1.3
8.000	0.0824	0.0639	0.0824	-10.8	-11.9	-10.8
> 8.000	0.0246	0.0029		-16.1	-25.4	

160 dB peak SPL

Octave Band CF (kHz)	Unweighted (J/m^2)	A-energy (J/m^2)	P-energy (J/m^2)	Unweighted* (dB)	A-energy* (dB)	P-energy* (dB)
< 0.125	3.0790	0.0016		4.9	-27.9	
0.125	0.1551	0.0038		-8.1	-24.2	
0.250	0.0535	0.0074	0.0011	-12.7	-21.3	-29.7
0.500	0.5723	0.2739	0.0361	-2.4	-5.6	-14.4
1.000	4.6410	4.6410	4.6410	6.7	6.7	6.7
2.000	2.6100	3.4407	2.6100	4.2	5.4	4.2
4.000	0.6592	0.8299	4.1593	-1.8	-0.8	6.2
8.000	0.3952	0.3068	0.3952	-4.0	-5.1	-4.0
> 8.000	0.1533	0.0180		-8.1	-17.4	

* dB re 1 J/m^2

Table III

Preexposure Threshold Means (dB) and Standard Deviations (dB) for all Groups

Peak SPL	#	0.5	1.0	2.0	4.0	8.0	11.2	16.0	
150 dB	1	17.9	3.9	8.9	-0.5	11.3	9.7	18.2	$\bar{X}$
		5.6	7.0	9.2	6.5	6.7	7.5	8.2	s
150 dB	10	14.6	-1.9	5.7	-3.2	10.8	9.2	18.6	$\bar{X}$
		4.7	4.1	4.5	4.0	6.8	8.0	5.7	s
150 dB	100	15.9	2.3	5.9	-3.4	9.2	9.6	14.9	$\bar{X}$
		5.3	5.2	4.1	3.8	4.5	7.0	6.9	s
155 dB	1	18.5	3.8	7.3	-2.6	10.5	13.0	22.7	$\bar{X}$
		4.3	6.6	7.6	5.1	6.4	11.3	6.6	s
155 dB	10	16.2	0.7	5.2	-6.3	11.2	9.8	20.7	$\bar{X}$
		4.1	4.9	7.4	8.6	5.0	8.4	8.1	s
155 dB	100	15.5	-0.6	8.1	-7.3	12.5	10.9	21.7	$\bar{X}$
		4.6	4.4	4.7	5.0	5.6	7.4	5.1	s
160 dB	1	18.5	3.9	7.8	-2.9	11.6	8.9	18.9	$\bar{X}$
		7.2	7.4	5.8	5.0	5.3	5.8	6.9	s
160 dB	10	16.8	0.8	5.8	-3.3	12.6	11.9	21.9	$\bar{X}$
		7.4	6.8	6.0	5.7	4.7	6.6	8.8	s
160 dB	100	16.9	-0.1	4.4	-3.7	9.6	11.8	20.2	$\bar{X}$
		5.4	4.4	5.9	6.6	5.7	7.2	8.8	s
Total		16.8	1.5	6.6	-3.7	11.0	10.5	19.7	$\bar{X}$
		5.5	6.0	6.3	5.9	5.6	7.7	7.5	s
		135	135	135	135	135	134	135	N
Miller (1970)		5.1	3.0	2.7	1.9	5.8	9.9	12.1	$\bar{X}$
		6.1	4.1	4.7	7.1	5.4	6.7	6.9	s
		36	36	36	36	36	34	36	N
Miller (1970) corrected for temporal integration (Henderson, 1969)		16.2	14.1	13.8	13.0	16.9	21.0	23.2	

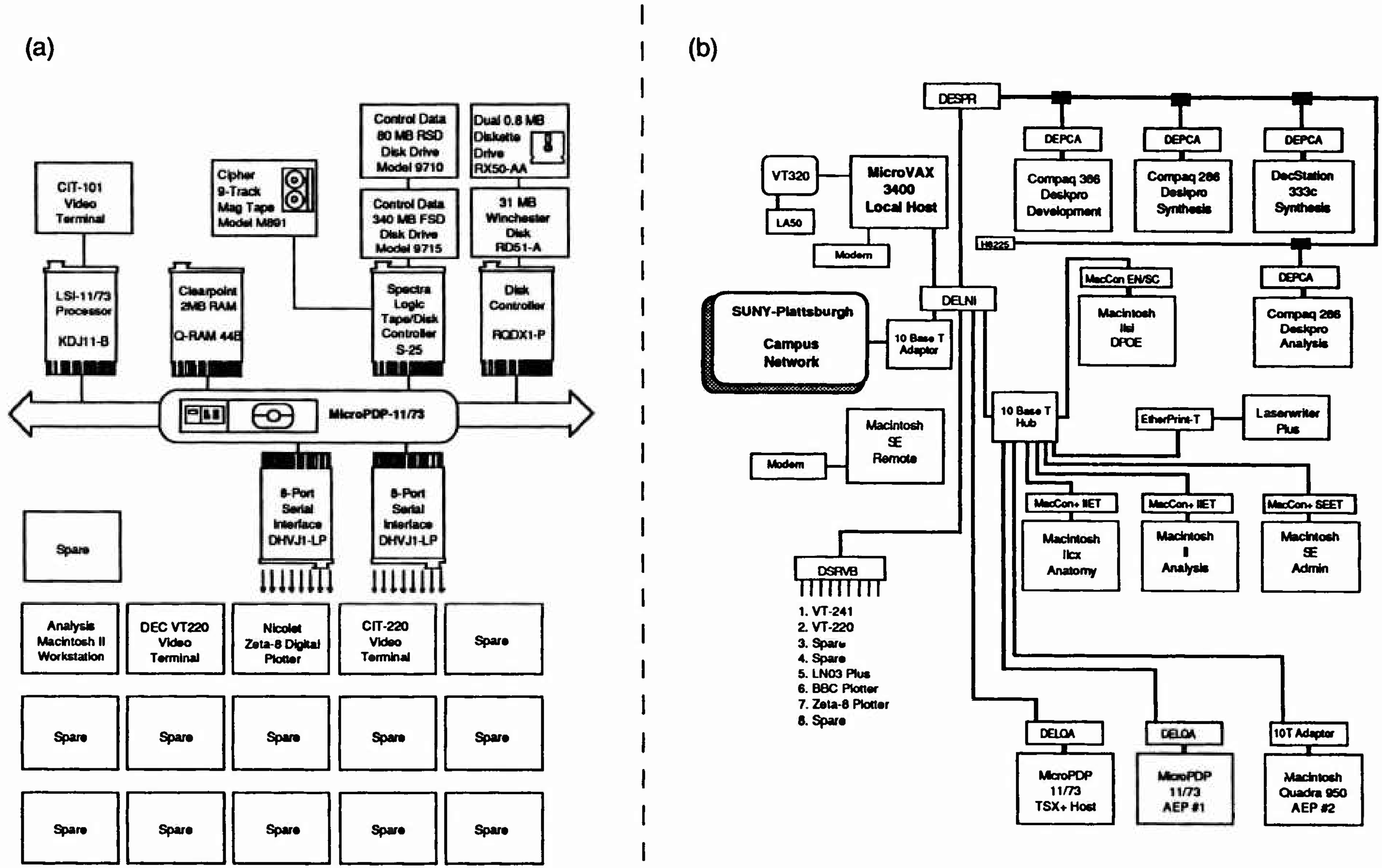


Figure 1. Schematic representations of (a) the Micro-PDP 11/73 time-sharing computer system and (b) the ARL local area network (LAN) with MicroVAX 3400 computer system.

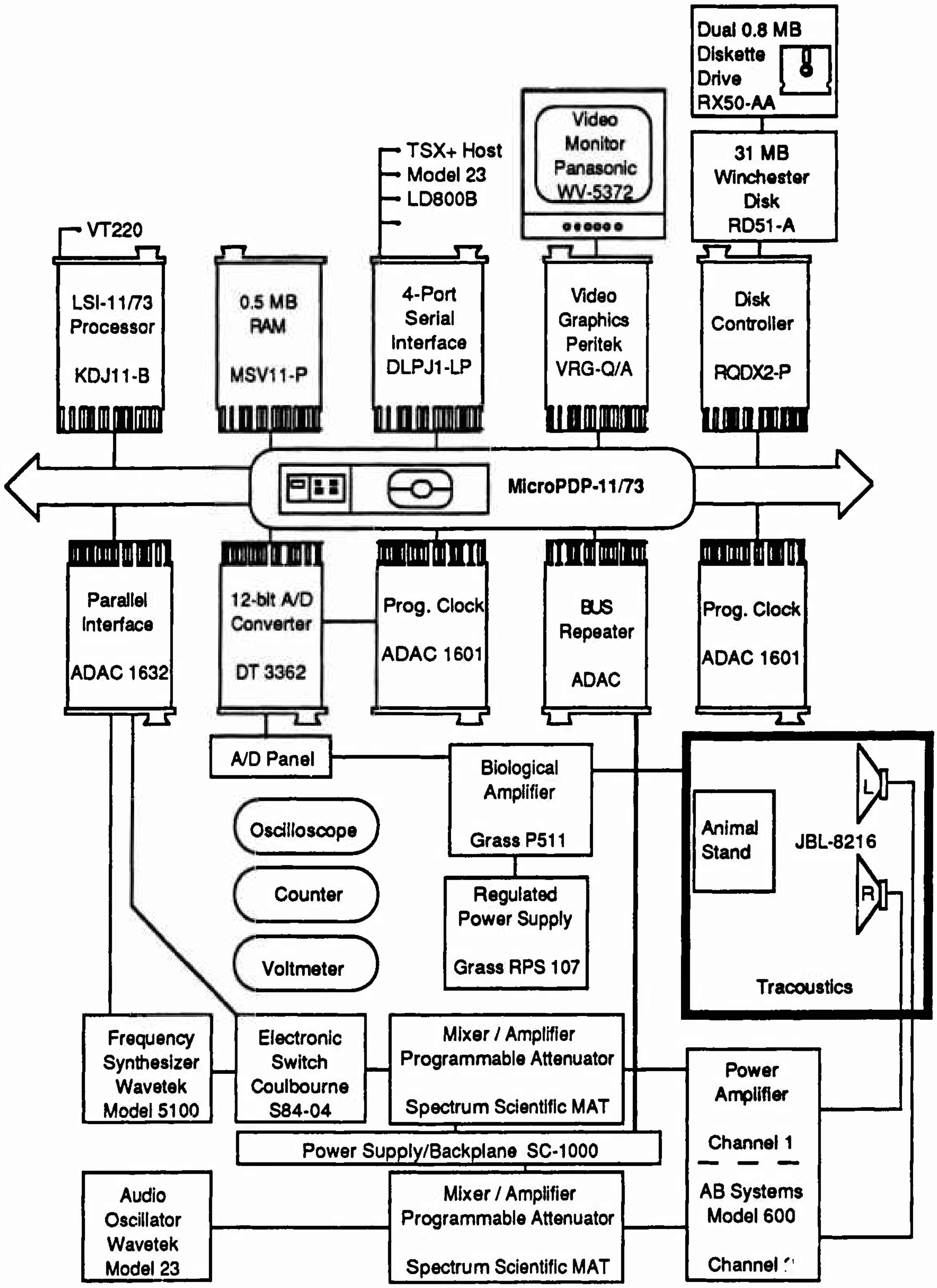


Figure 2. Schematic representation of auditory evoked potential computer system.

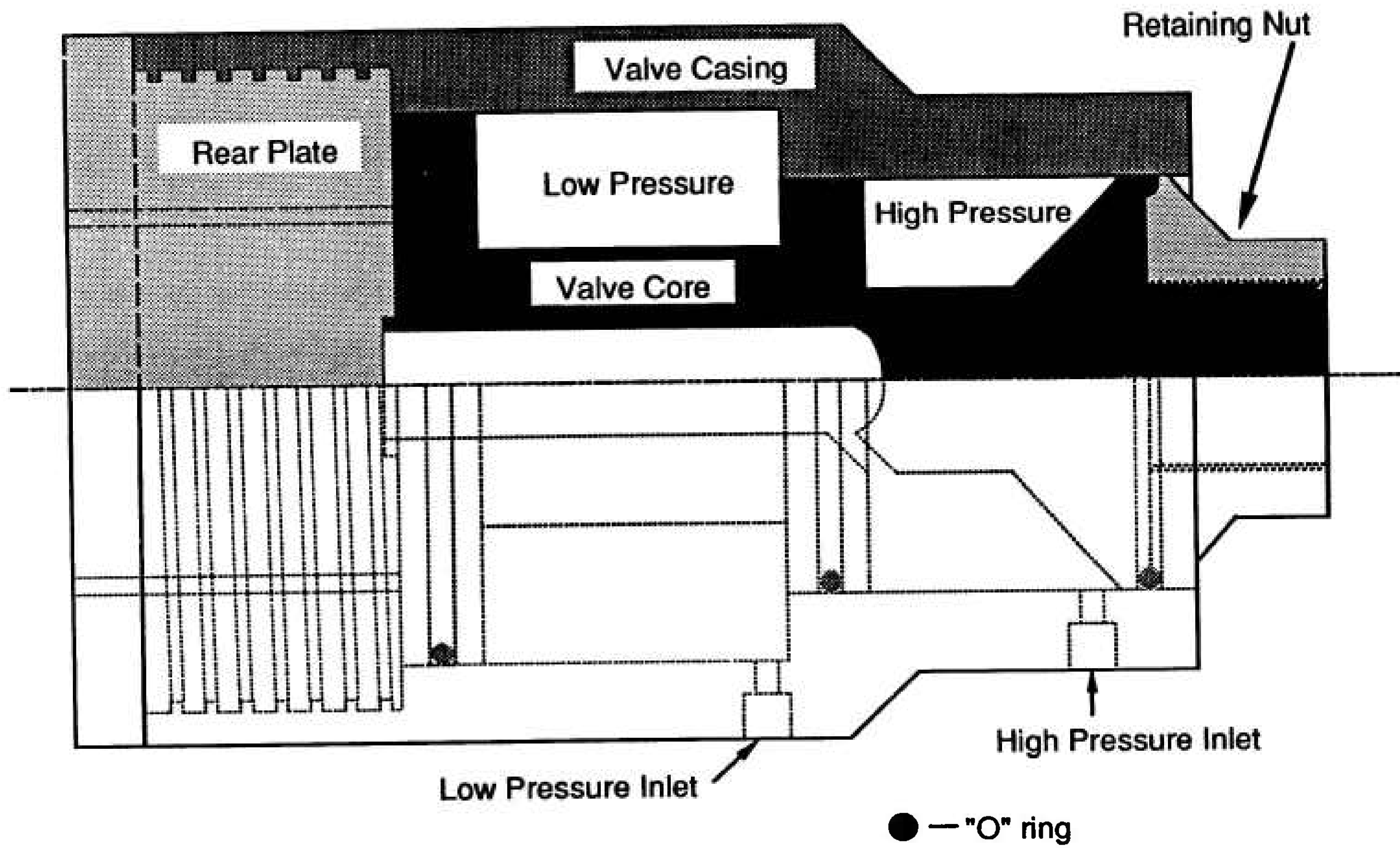


Figure 3. Schematic of the Lamont Fast-acting Valve Used for Source III.

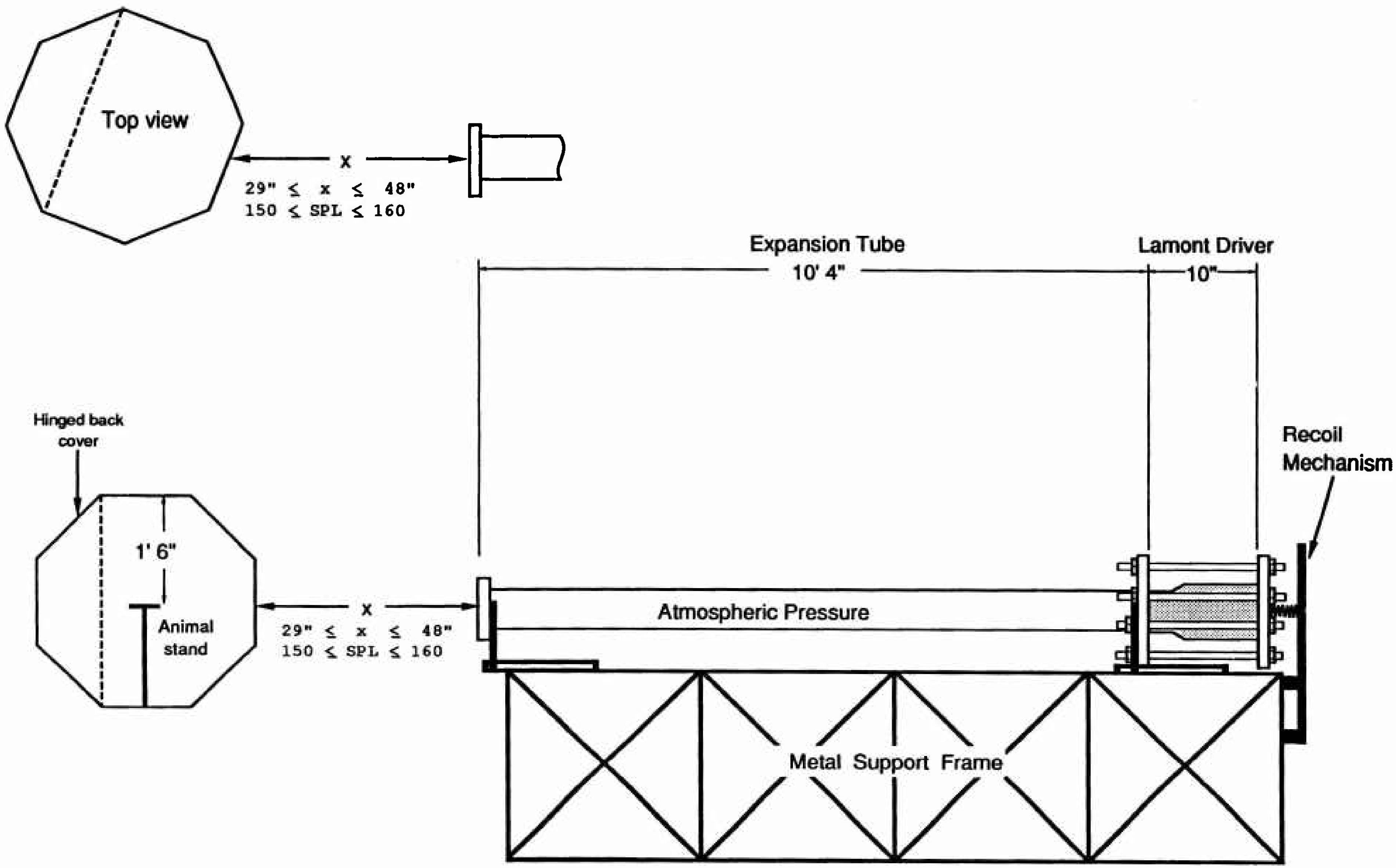


Figure 4. Schematic of Source III shock tube with reverberant chamber.

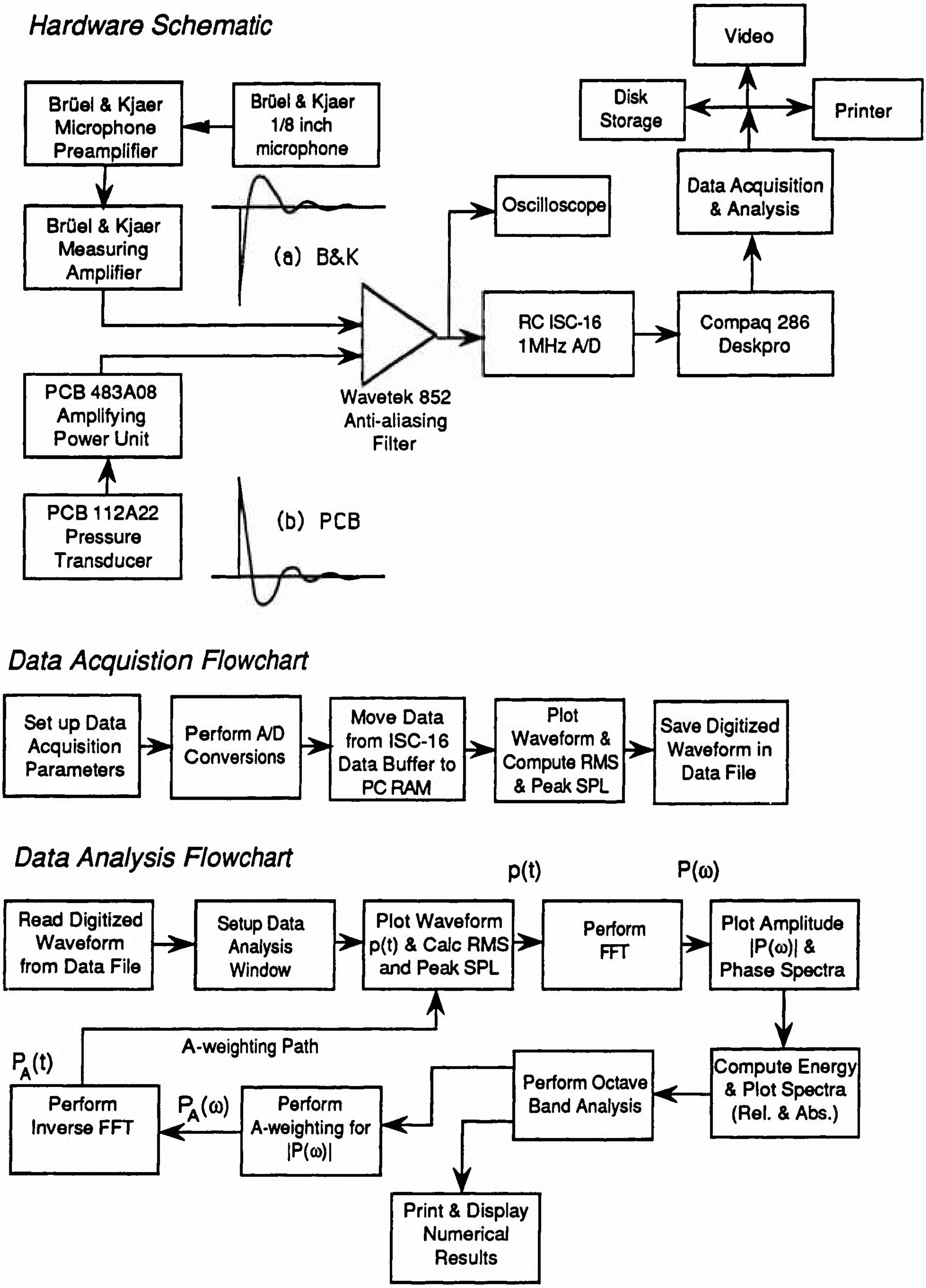


Figure 5. Configuration of the MS-DOS PC-Based Data Acquistion and Analysis System

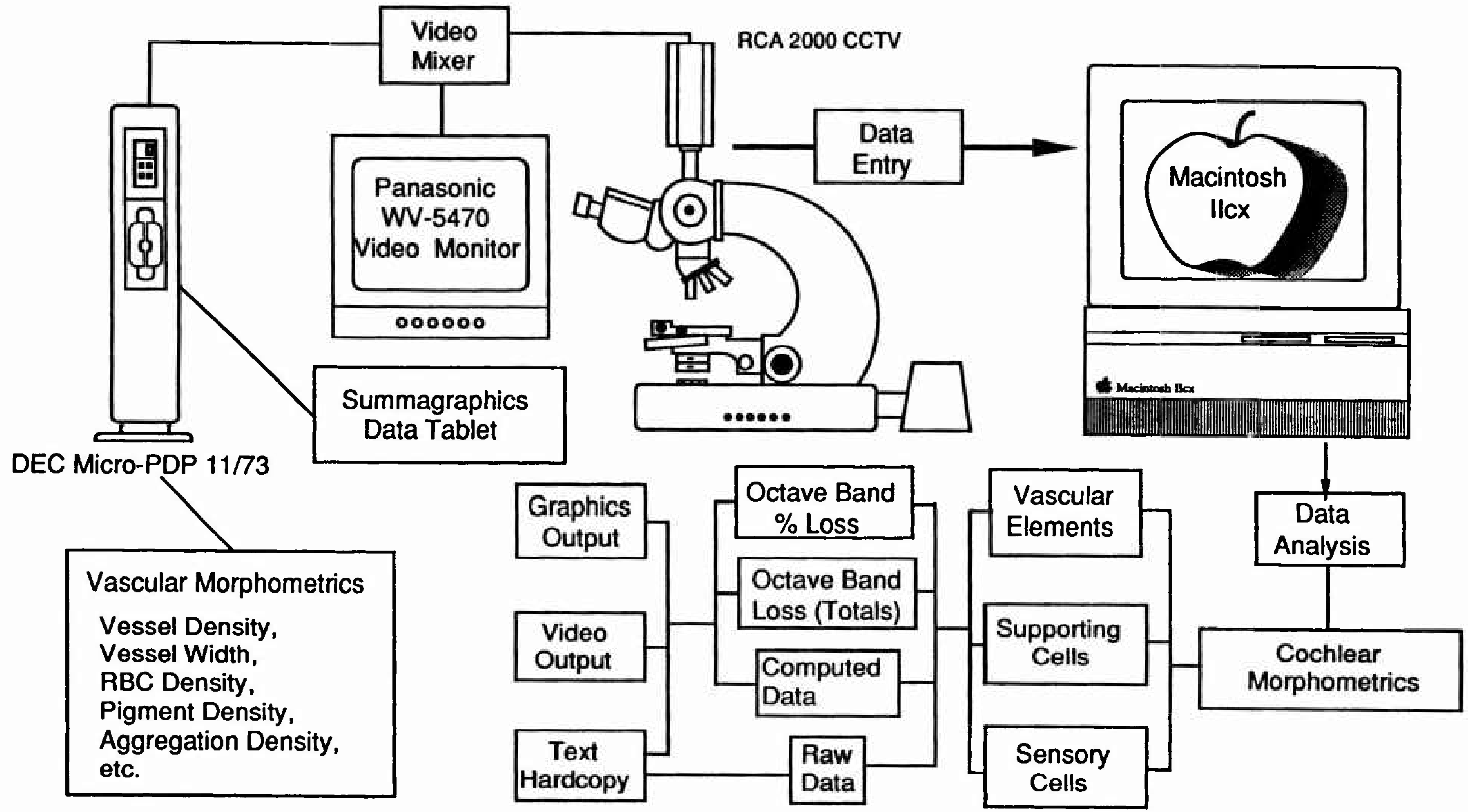


Figure 6. Anatomy Laboratory Temporal Bone Morphometric Analysis Systems.

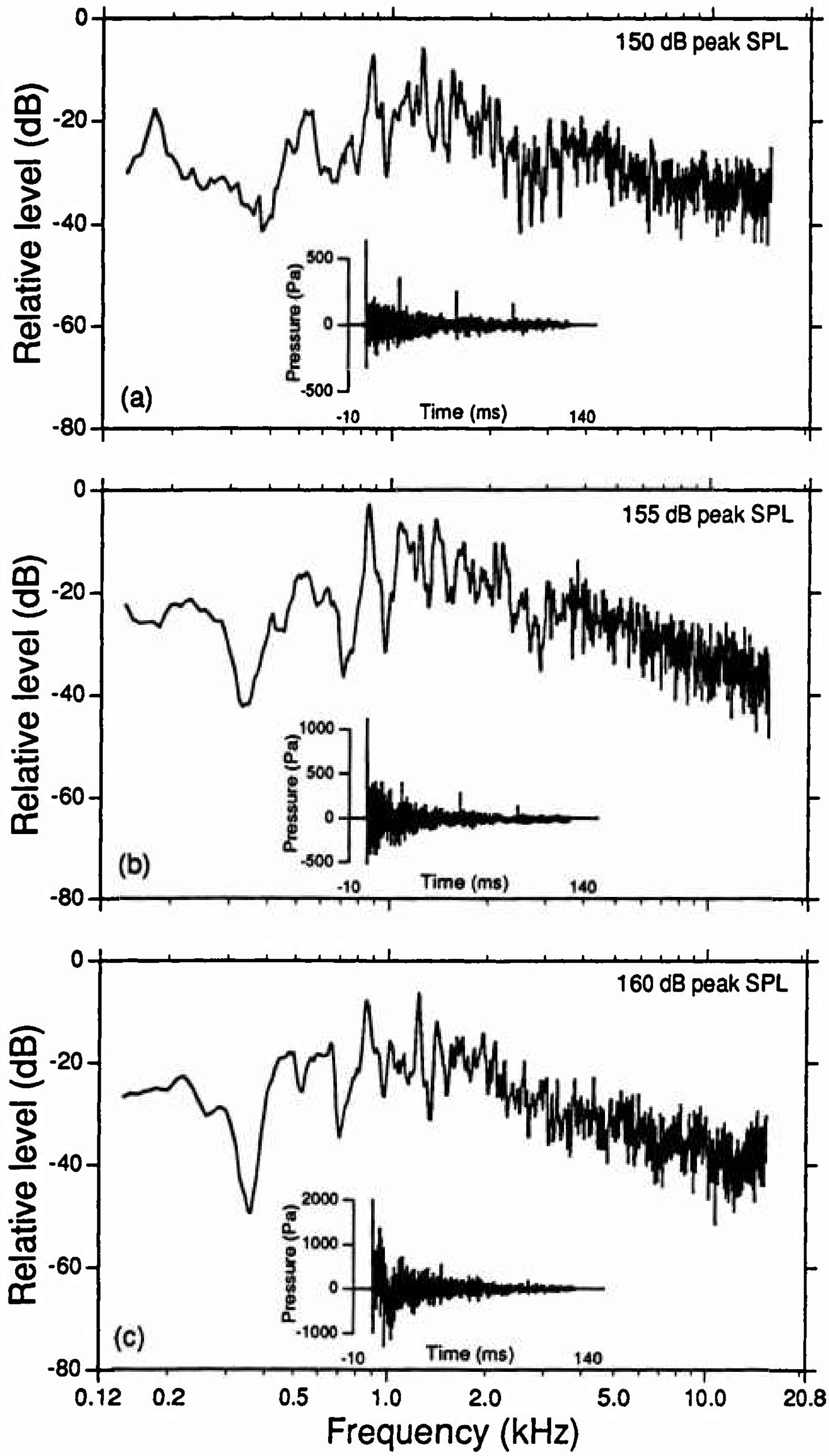


Figure 7. Relative frequency spectra and pressure-time waveforms for the (a) 150 dB, (b) 155 dB and (c) 160 dB peak SPL reverberant blast waves produced by Source III.

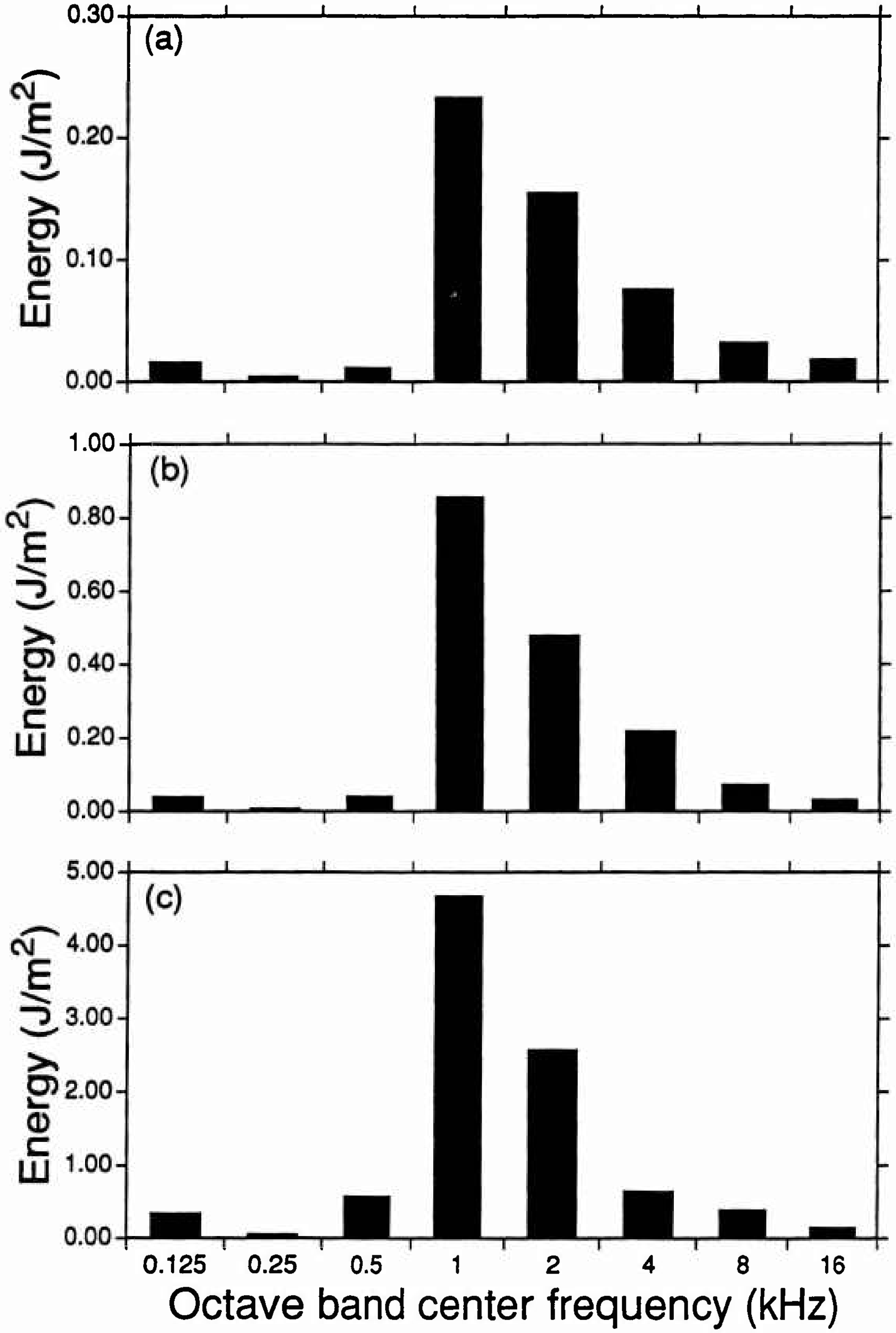


Figure 8. Unweighted octave band sound energies for a reverberant impulse generated by Source III having a peak SPL of (a) 150 dB, (b) 155 dB and (c) 160 dB.

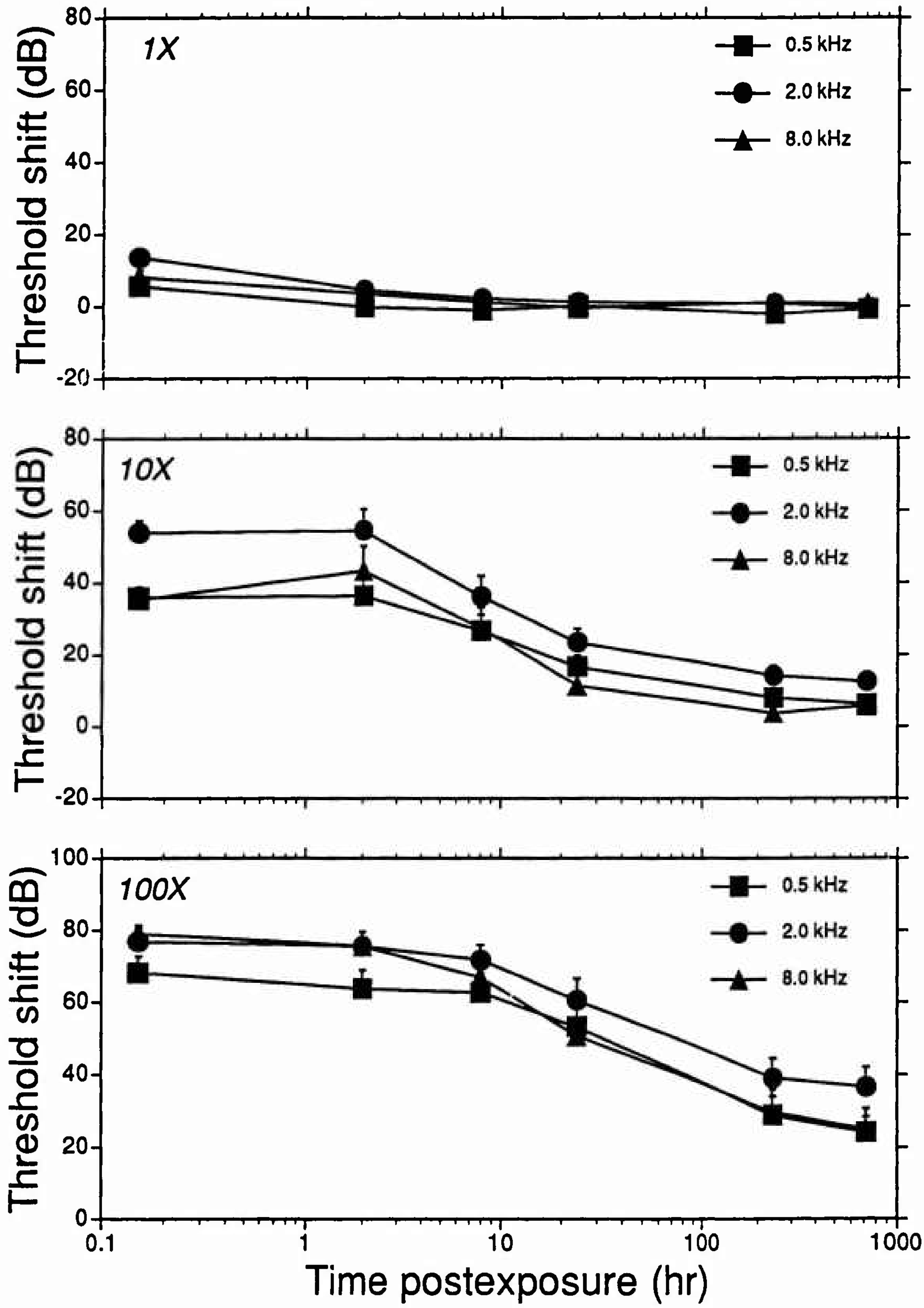


Figure 9. Recovery of threshold shift for all groups exposed to one, 10 or 100 reverberant blast waves at 150 dB peak SPL produced by Source III. The error bars represent one standard error of the mean.

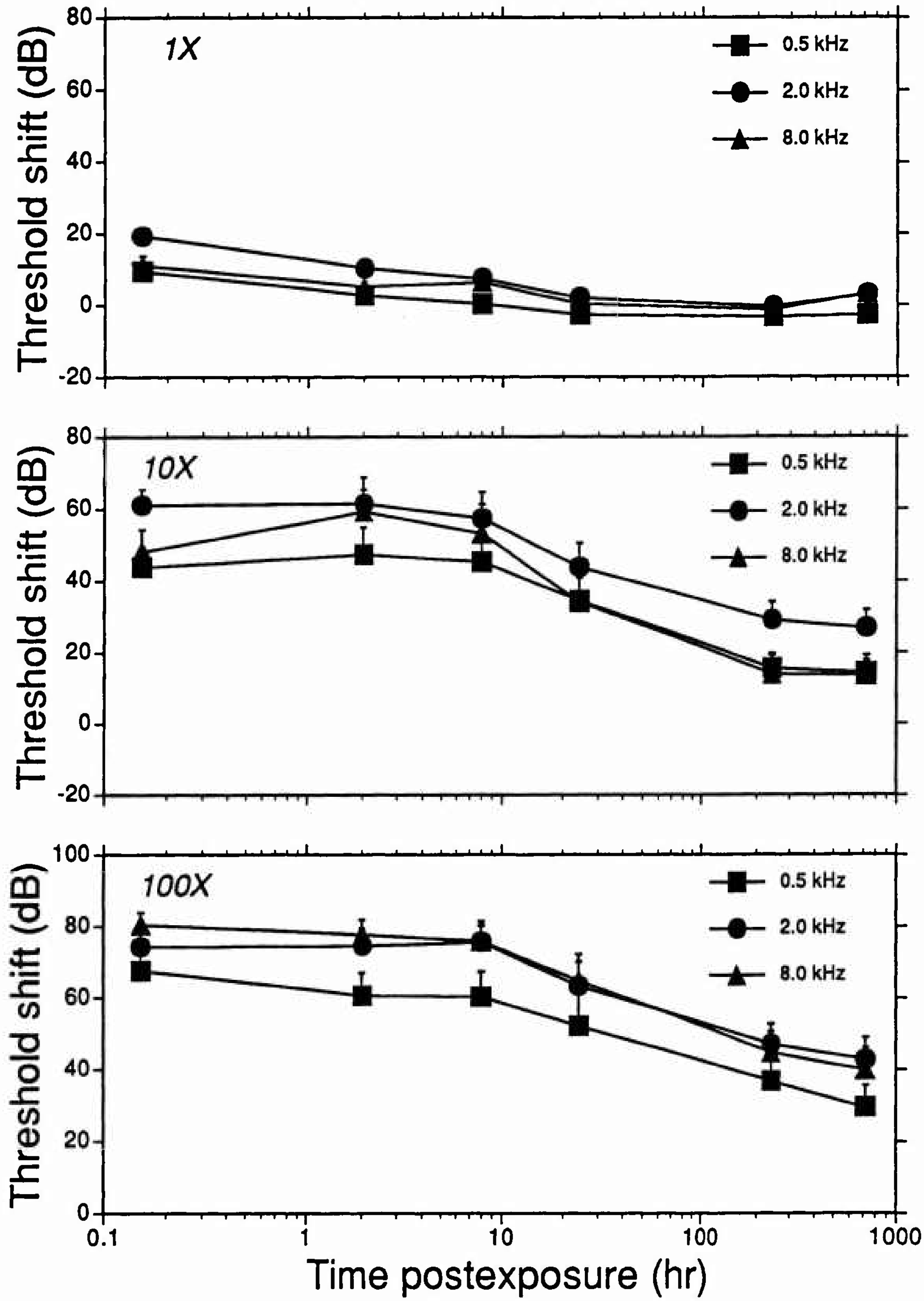


Figure 10. Recovery of threshold shift for all groups exposed to one, 10 or 100 reverberant blast waves at 155 dB peak SPL produced by Source III. The error bars represent one standard error of the mean.

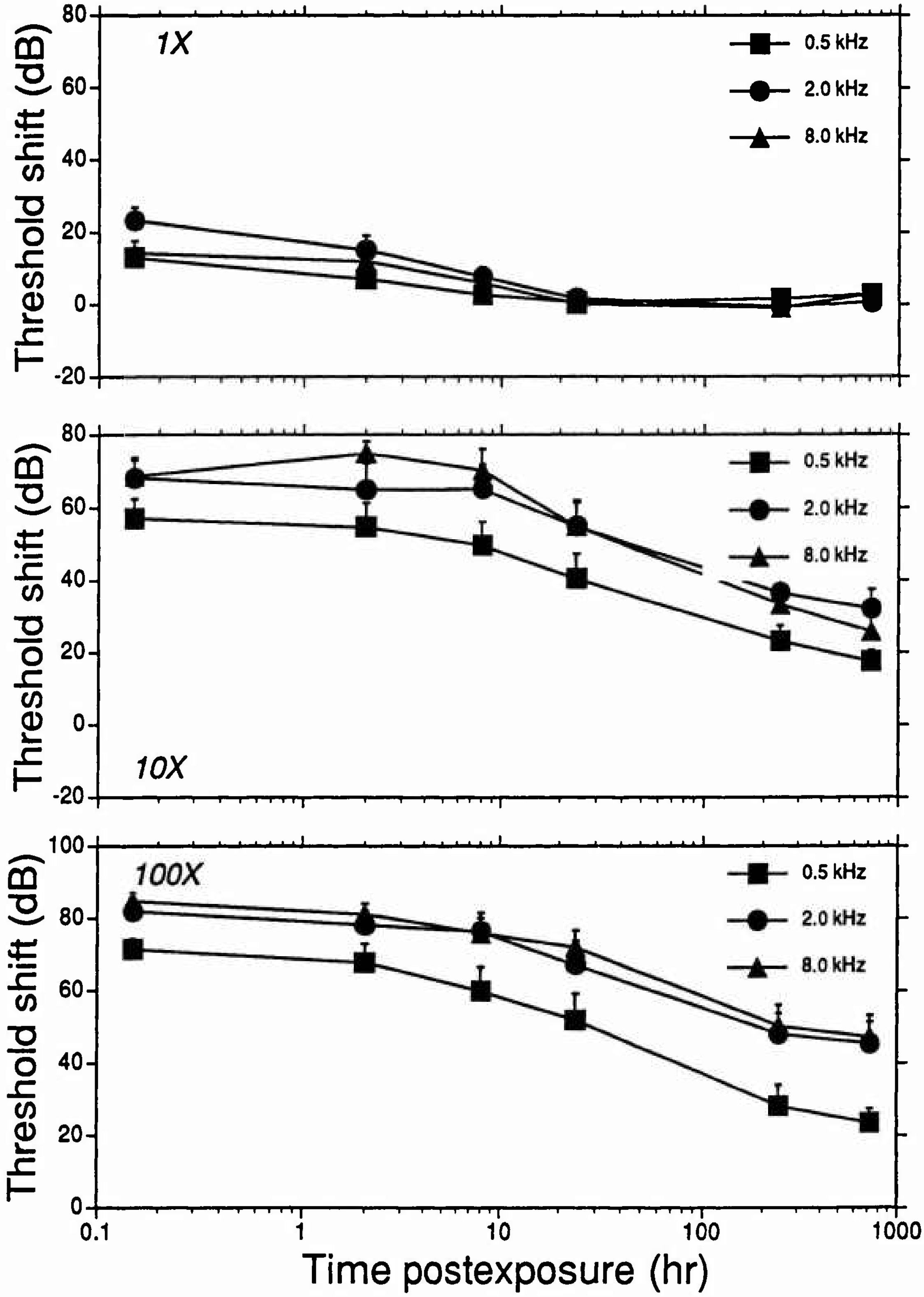


Figure 11. Recovery of threshold shift for all groups exposed to one, 10 or 100 reverberant blast waves at 160 dB peak SPL produced by Source III. The error bars represent one standard error of the mean.

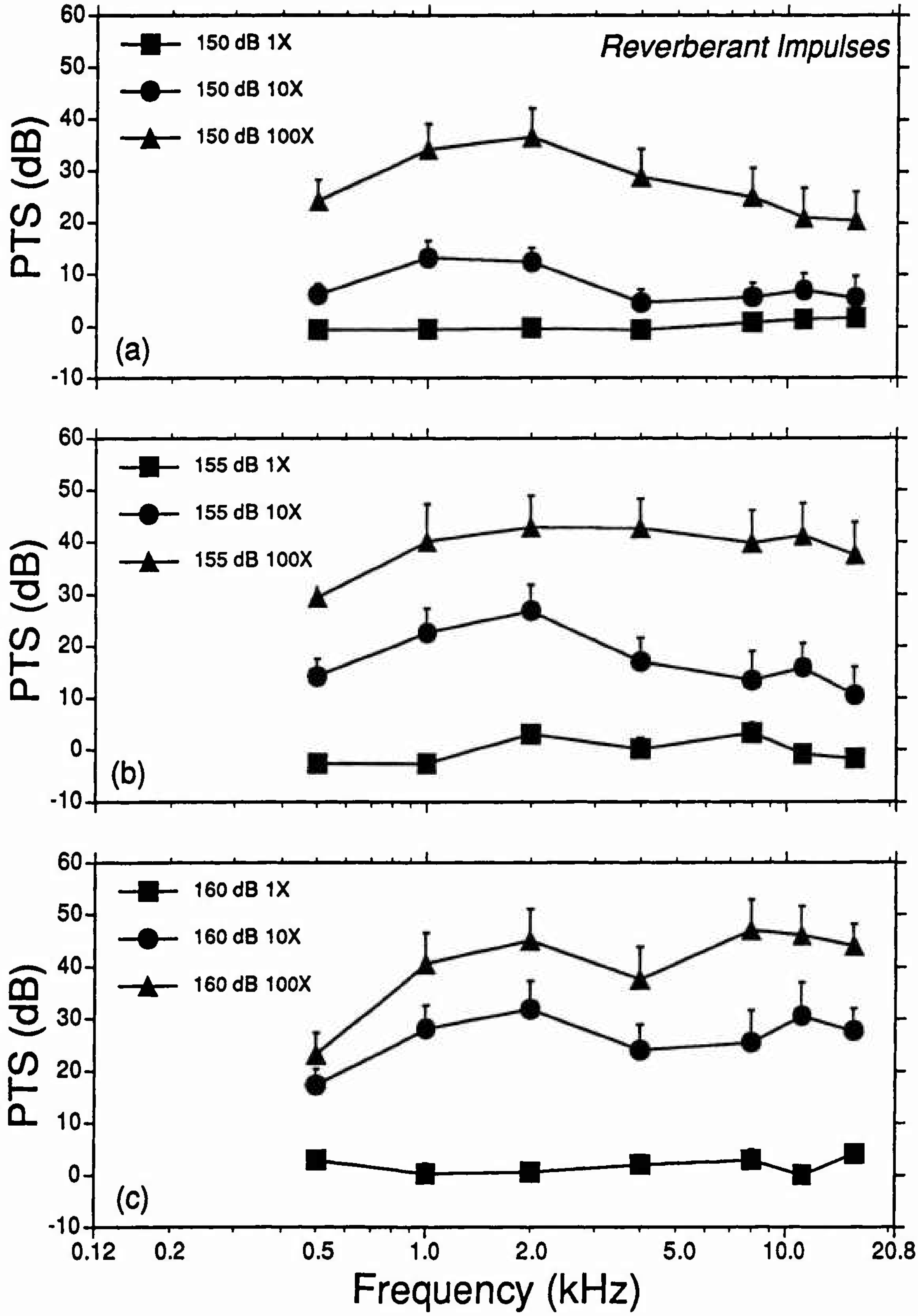


Figure 12. Permanent threshold shift for all groups exposed to one, 10 or 100 reverberant blast waves at (a) 150 dB, (b) 155 dB or (c) 160 dB peak SPL produced by Soruce III. The error bars represent one standard error of the mean.

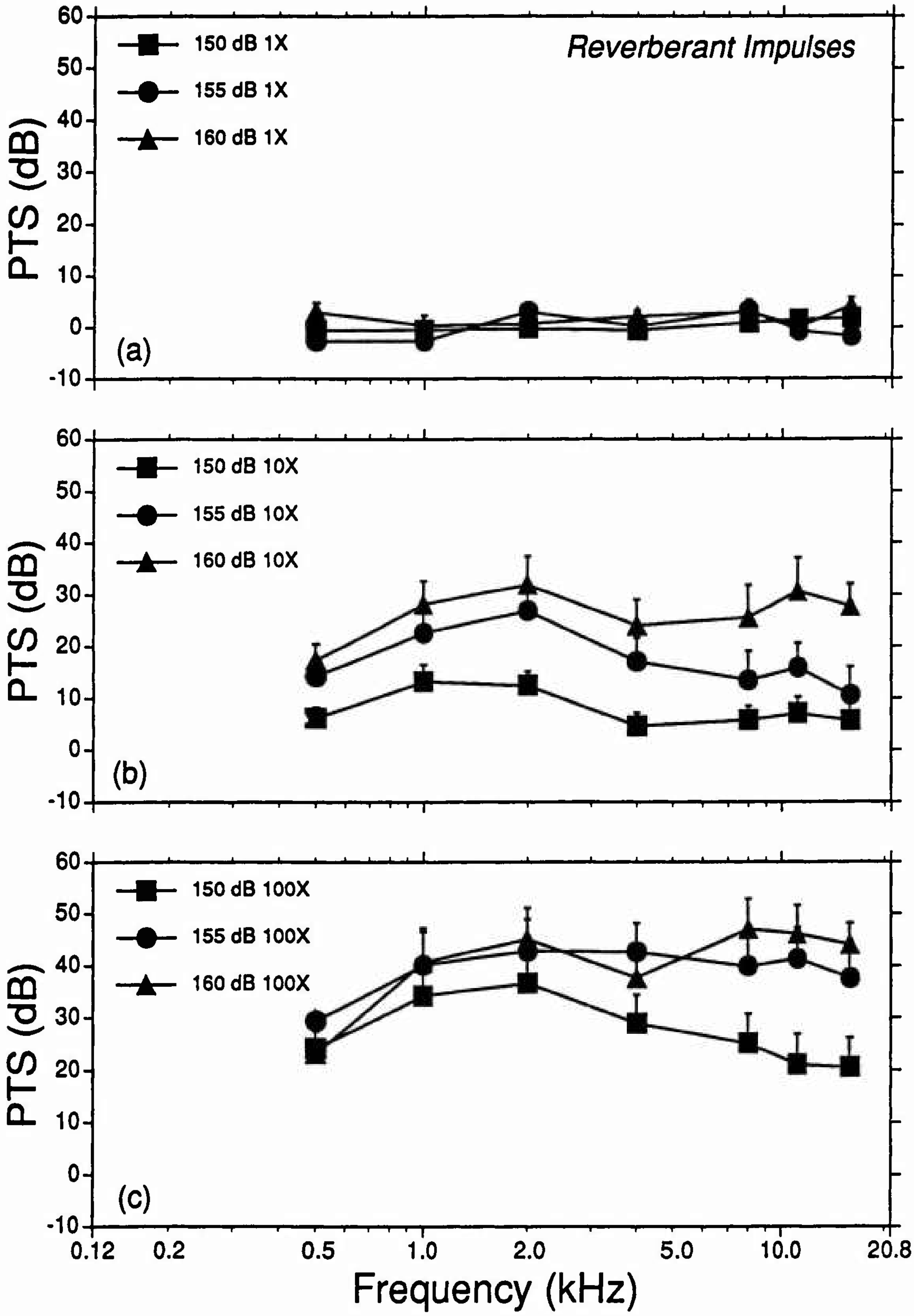


Figure 13. Permanent threshold shift for all groups exposed to 150, 155 or 160 dB peak SPL reverberant blast waves for (a) one, (b) 10 or (c) 100 blast waves produced by Source III. The error bars represent one standard error of the mean.

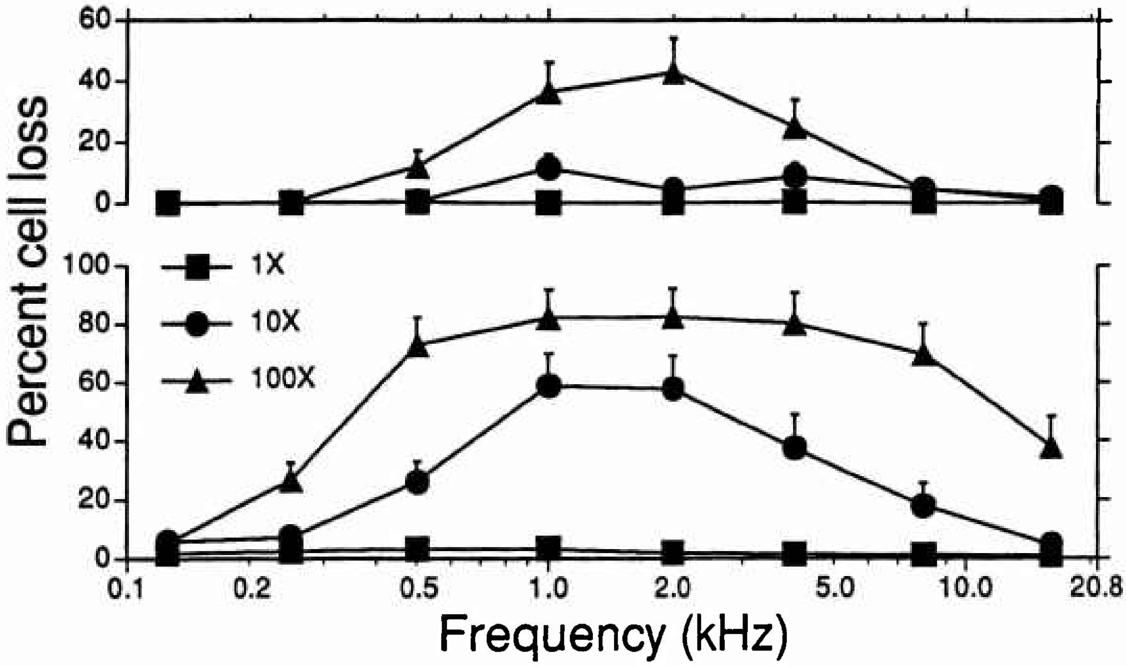


Figure 14. Sensory cell losses for all groups exposed to one, 10 or 100 reverberant blast waves at 155 dB peak SPL produced by Source III. The error bars represent one standard error of the mean.

Appendix

Example Data Archive

Guide to the Data Archive

The raw data and summary statistics for each experimental group are included in a data archive. The following pages give an example how the information from one group is arranged in the archive and present a brief description of the contents of the data archive. In the midterm report only an example archive of a single exposure group is included. The entire data archive will be printed in this format and submitted to the COR at the termination of this contract.

Page	**Description**
A-1	Group Title Page

The group title page indicates the exposure that each animal in this group received [e.g., 150 dB peak SPL, 1X (single impulse)] and the subjects that comprise this group. Other notes may be indicated.

A-2	Figures

The upper left panel depicts the mean preexposure thresholds for this group. The error bars on this figure and all other figures in the appendices represent one standard error of the mean. If a bar is not present, the standard error was less than the size of the symbol.

The lower left panel presents the group mean PTS measured at least 30 days after exposure.

The upper right panel displays the group mean threshold shift measured immediately after exposure and at intervals of 2, 8, 24, 240 and 720 hours after exposure at the three test frequencies (0.5, 2.0, 8.0 kHz). (The 720-hour measurement consists of the average of three different measurements made at least 30 days after exposure.)

The lower right panel presents the mean percent inner and outer hair cell losses in lengths along the basilar membrane that correspond to an octave band.

A-3 to A-4	Preexposure, Postexposure and PTS Measurements

This page tabulates the pre- and postexposure thresholds (in dB SPL) for each subject as well as the group mean, standard deviation and standard error of the mean. PTS is computed by subtracting the preexposure threshold from the postexposure threshold for each subject.

A-5 to A-6	Combined Threshold Shift

The threshold shifts at the three postexposure test frequencies (0.5, 2.0, 8.0 kHz) are tabulated in this table. Threshold shift is computed by subtracting the preexposure threshold from the postexposure threshold at each recovery time. An asterisk by a threshold signifies that no response was present at the maximum acoustic output of the AEP test system. The maximum level (in dB SPL) was used as the subject's threshold if no response was present. Therefore, it is possible that a measure of CTS may be underestimated in some groups.

A-7 Total Cell Loss Summary

The total sensory cell losses for this group are presented in the top portion of this table. The lower portion of the table presents the mean and standard deviation for the total number of inner and outer hair cells missing along octave band lengths of the cochlea.

A-8 to A-13 Total Cell Losses

The total sensory cell losses in octave band lengths of the cochlea for each animal that comprises the exposure group are presented in this table. Also included at the end of the table are the group mean, standard deviation and standard error of the mean for each octave band length.

A-14 to A-18 Percent Sensory Cell Losses

This table presents the percent sensory cell losses in octave band lengths of the cochlea for each animal in this group. Also included are the means, standard deviation and standard error of the mean for each sensory cell and octave band length.

A-19 to A-33 Cochleograms and PTS Audiograms

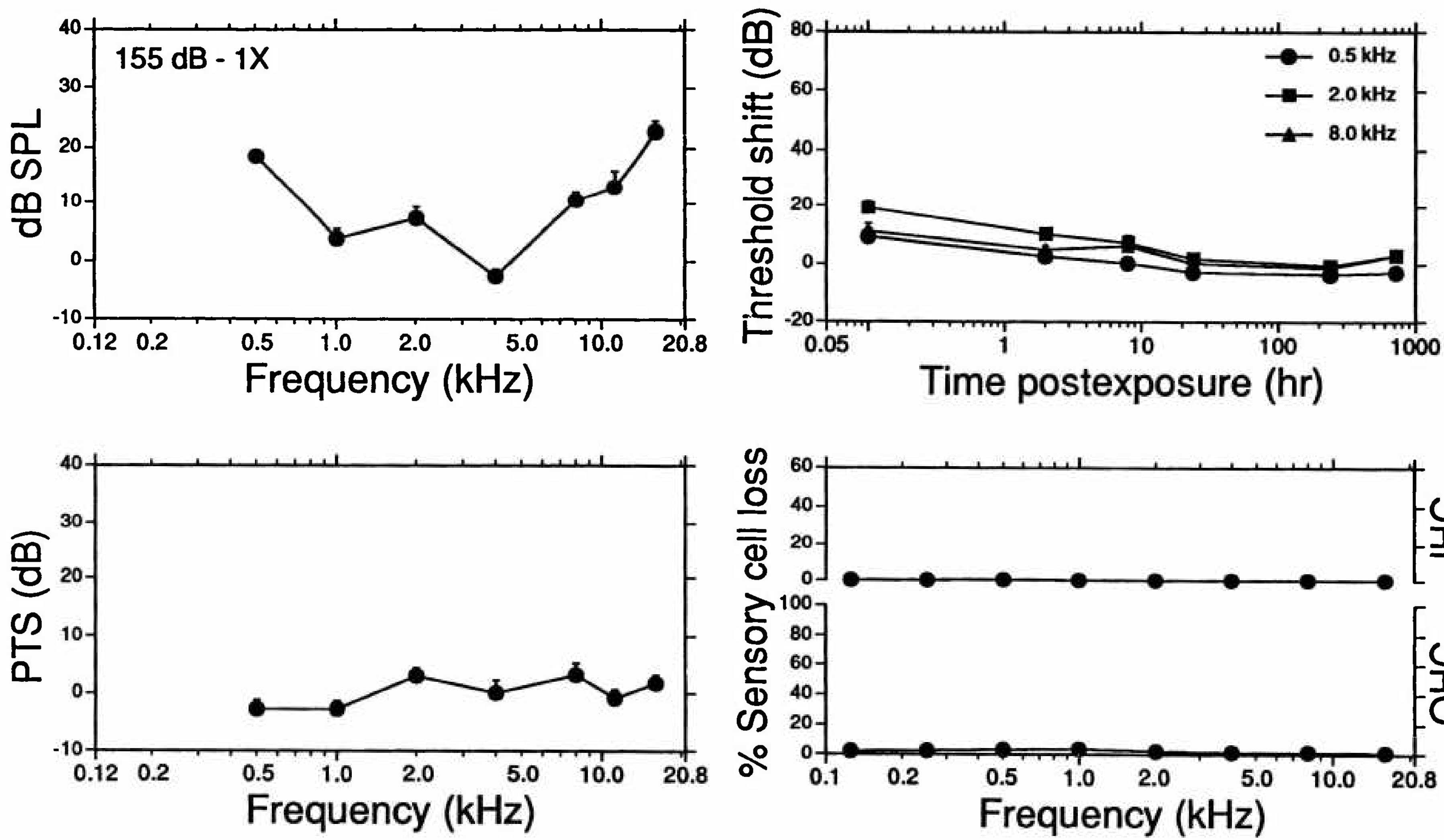
These figures show: (1) the distribution of inner and outer hair cell loss across the length of the basilar membrane (i.e., cochleograms) and the corresponding PTS audiogram; (2) the distribution of outer hair cell loss by row and (3) the distribution of pillar cell loss by row for each animal in the exposure group. The cochleograms show the percent inner and outer hair cell losses for each 0.24 mm segment of the basilar membrane. The PTS audiogram is plotted to allow easy comparison of the PTS and cell loss resulting from the noise exposure.

Summary Data for the Group Exposed to:

Source III Reverberant Impulse

155 dB peak SPL - 1X

Animal #		
1344	-	Completed the Entire Protocol
1341	-	Completed the Entire Protocol
1354	-	Completed the Entire Protocol
1356	-	Completed the Entire Protocol
1363	-	Completed the Entire Protocol
1368	-	Completed the Entire Protocol
1385	-	Completed the Entire Protocol
1390	-	Completed the Entire Protocol
1402	-	Completed the Entire Protocol
1407	-	Completed the Entire Protocol
1408	-	Completed the Entire Protocol
1410	-	Completed the Entire Protocol
1434	-	Completed the Entire Protocol
1440	-	Completed the Entire Protocol
1441	-	Completed the Entire Protocol


155 dB - 1X
dB SPL
Frequency (kHz)
Threshold shift (dB)
Time postexposure (hr)
0.5 kHz
2.0 kHz
8.0 kHz
PTS (dB)
% Sensory cell loss
IHC
OHC

Source III Reverberant Impulse
155 dB peak SPL - 1X

Preexposure thresholds (dB SPL)

Animal\kHz	0.5	1.0	2.0	4.0	8.0	11.2	16.0
1334	25.8	9.2	4.2	5.8	9.2	17.5	34.2
1341	19.2	-2.5	-0.8	-5.8	-2.5	-12.5	12.5
1354	15.8	5.8	5.8	-4.2	7.5	12.5	15.8
1356	19.2	-0.8	7.5	-2.5	10.8	4.2	20.8
1363	15.8	0.8	-0.8	-4.2	14.2	7.5	15.8
1368	15.8	7.5	9.2	0.8	4.2	10.8	15.8
1385	22.5	5.8	5.8	-0.8	10.8	15.8	22.5
1390	20.8	20.8	14.2	5.8	5.8	22.5	22.5
1402	17.5	2.5	12.5	-7.5	2.5	*****	25.8
1407	17.5	4.2	9.2	-0.8	12.5	14.2	22.5
1408	9.2	-5.8	-7.5	-14.2	10.8	9.2	22.5
1410	19.2	4.2	19.2	0.8	20.8	29.2	32.5
1434	19.2	0.8	17.5	-5.8	19.2	30.8	25.8
1440	14.2	-4.2	-0.8	-5.8	14.2	0.8	19.2
1441	25.8	9.2	14.2	-0.8	17.5	19.2	32.5
Mean	18.5	3.8	7.3	-2.6	10.5	13.0	22.7
S.D.	4.3	6.6	7.6	5.1	6.4	11.3	6.6
S.E.	1.1	1.7	2.0	1.3	1.6	3.0	1.7

Postexposure thresholds (dB SPL)

Animal\kHz	0.5	1.0	2.0	4.0	8.0	11.2	16.0
1334	12.5	-2.5	4.2	-17.5	19.2	12.5	34.2
1341	12.5	-4.2	9.2	-4.2	14.2	-5.8	17.5
1354	20.8	9.2	15.8	-4.2	20.8	17.5	10.8
1356	17.5	-0.8	12.5	0.8	14.2	7.5	14.2
1363	14.2	2.5	12.5	0.8	9.2	-0.8	0.8
1368	15.8	5.8	10.8	-4.2	15.8	15.8	12.5
1385	10.8	-0.8	10.8	-0.8	15.8	9.2	17.5
1390	25.8	19.2	17.5	10.8	14.2	19.2	29.2
1402	14.2	-0.8	5.8	-17.5	-0.8	7.5	27.5
1407	12.5	0.8	9.2	-0.8	20.8	12.5	24.2
1408	12.5	-10.8	-7.5	-12.5	7.5	2.5	19.2
1410	24.2	5.8	20.8	7.5	12.5	24.2	35.8
1434	20.8	0.8	17.5	2.5	20.8	30.8	25.8
1440	9.2	-0.8	4.2	5.8	10.8	9.2	15.8
1441	14.2	-5.8	10.8	-4.2	10.8	15.8	29.2
Mean	15.8	1.2	10.3	-2.5	13.7	11.8	20.9
S.D.	5.0	7.0	6.9	8.3	5.9	9.4	9.6
S.E.	1.3	1.8	1.8	2.1	1.5	2.4	2.5

Source III Reverberant Impulse
155 dB peak SPL - 1X

Permanent threshold shift (dB)

Animal\kHz	0.5	1.0	2.0	4.0	8.0	11.2	16.0
1334	-13.3	-11.7	0.0	-23.3	10.0	-5.0	0.0
1341	-6.7	-1.7	10.0	1.7	16.7	6.7	5.0
1354	5.0	3.3	10.0	0.0	13.3	5.0	-5.0
1356	-1.7	0.0	5.0	3.3	3.3	3.3	-6.7
1363	-1.7	1.7	13.3	5.0	-5.0	-8.3	-15.0
1368	0.0	-1.7	1.7	-5.0	11.7	5.0	-3.3
1385	-11.7	-6.7	5.0	0.0	5.0	-6.7	-5.0
1390	5.0	-1.7	3.3	5.0	8.3	-3.3	6.7
1402	-3.3	-3.3	-6.7	-10.0	-3.3	*****	1.7
1407	-5.0	-3.3	0.0	0.0	8.3	-1.7	1.7
1408	3.3	-5.0	0.0	1.7	-3.3	-6.7	-3.3
1410	5.0	1.7	1.7	6.7	-8.3	-5.0	3.3
1434	1.7	0.0	0.0	8.3	1.7	0.0	0.0
1440	-5.0	3.3	5.0	11.7	-3.3	8.3	-3.3
1441	-11.7	-15.0	-3.3	-3.3	-6.7	-3.3	-3.3
Mean	-2.7	-2.7	3.0	0.1	3.2	-0.8	-1.8
S.D.	6.2	5.2	5.3	8.4	7.9	5.5	5.4
S.E.	1.6	1.4	1.4	2.2	2.0	1.5	1.4

Source III Reverberant Impulse
155 dB peak SPL - 1X

Combined threshold shift (dB)

Frequency 0.5 kHz

Animal\Hr	0	2	8	24	240	Max
1334	-13.3	-3.3	-3.3	-18.3	-13.3	-3.3
1341	-1.7	-6.7	-1.7	-6.7	-11.7	-1.7
1354	16.7	6.7	11.7	6.7	6.7	16.7
1356	8.3	8.3	3.3	-1.7	-1.7	8.3
1363	11.7	-3.3	1.7	1.7	-3.3	11.7
1368	6.7	16.7	1.7	6.7	1.7	16.7
1385	35.0	-5.0	-10.0	-5.0	-5.0	35.0
1390	21.7	11.7	11.7	1.7	1.7	21.7
1402	15.0	5.0	5.0	0.0	5.0	15.0
1407	5.0	0.0	-5.0	-5.0	-5.0	5.0
1408	8.3	3.3	-1.7	-1.7	-6.7	8.3
1410	3.3	-1.7	-1.7	3.3	3.3	3.3
1434	8.3	3.3	-1.7	-6.7	-11.7	8.3
1440	8.3	3.3	-1.7	-1.7	3.3	8.3
1441	6.7	1.7	-3.3	-13.3	-13.3	6.7
Mean	9.3	2.7	0.3	-2.7	-3.3	10.7
S.D.	10.7	6.4	5.8	6.9	6.9	9.6
S.E.	2.8	1.7	1.5	1.8	1.8	2.5

Frequency 2.0 kHz

Animal\Hr	0	2	8	24	240	Max
1334	23.3	8.3	28.3	3.3	8.3	28.3
1341	13.3	13.3	8.3	8.3	8.3	13.3
1354	16.7	16.7	16.7	11.7	6.7	16.7
1356	15.0	10.0	5.0	0.0	-5.0	15.0
1363	28.3	13.3	18.3	8.3	-1.7	28.3
1368	8.3	13.3	13.3	-1.7	-1.7	13.3
1385	41.7	16.7	6.7	1.7	1.7	41.7
1390	8.3	8.3	3.3	-1.7	-1.7	8.3
1402	30.0	5.0	5.0	-5.0	-10.0	30.0
1407	18.3	13.3	3.3	3.3	-1.7	18.3
1408	25.0	15.0	10.0	10.0	5.0	25.0
1410	8.3	3.3	3.3	8.3	3.3	8.3
1434	10.0	0.0	0.0	0.0	-10.0	10.0
1440	18.3	13.3	3.3	-1.7	8.3	18.3
1441	23.3	3.3	-15.7	-15.7	-15.7	23.3
Mean	19.2	10.2	7.3	2.0	-0.4	19.9
S.D.	9.5	5.3	9.8	7.0	7.4	9.4
S.E.	2.5	1.4	2.5	1.8	1.9	2.4

Source III Reverberant Impulse
155 dB peak SPL - 1X

Combined threshold shift (dB)

Frequency 8.0 kHz

Animal\Hr	0	2	8	24	240	Max
1334	23.3	8.3	8.3	8.3	3.3	23.3
1341	5.0	5.0	20.0	10.0	15.0	20.0
1354	5.0	0.0	5.0	10.0	5.0	10.0
1356	6.7	11.7	6.7	-3.3	6.7	11.7
1363	3.3	-6.7	-1.7	-16.7	-6.7	3.3
1368	3.3	13.3	33.3	8.3	-1.7	33.3
1385	41.7	1.7	1.7	6.7	1.7	41.7
1390	6.7	11.7	6.7	-3.3	-8.3	11.7
1402	10.0	5.0	5.0	0.0	-5.0	10.0
1407	10.0	0.0	5.0	-5.0	0.0	10.0
1408	21.7	6.7	1.7	-3.3	-13.3	21.7
1410	6.7	1.7	1.7	-8.3	-8.3	6.7
1434	3.3	3.3	3.3	-1.7	-1.7	3.3
1440	8.3	8.3	3.3	13.3	-1.7	13.3
1441	10.0	5.0	-5.0	-10.0	-5.0	10.0
Mean	11.0	5.0	6.3	0.3	-1.3	15.3
S.D.	10.4	5.3	9.3	8.7	7.1	10.9
S.E.	2.7	1.4	2.4	2.3	1.8	2.8

Source III Reverberant Impulses
155 dB peak SPL - 1X

Total number of cochlear sensory cells missing

Animal number	Inner hair cells	1st row outer hair cells	2nd row outer hair cells	3rd row outer hair cells	Total outer hair cells
1334	1	3	104	35	142
1341	7	15	48	87	150
1354	10	322	114	172	608
1356	10	28	52	90	170
1363	1	12	46	84	142
1368	4	63	73	94	230
1385	1	12	19	78	109
1390	6	9	30	34	73
1402	2	15	36	35	86
1407	0	15	37	29	81
1408	0	20	57	67	144
1410	5	5	28	32	65
1434	0	4	24	71	99
1440	1	13	27	78	118
1441	0	17	43	50	110
Group mean	3				155
S.D.	4				132
S.E.	1				34

Total sensory cell losses over octave band lengths of the cochlea centered at the frequencies indicated

Octave band center frequency	Inner hair cells	Outer hair cells
Group means		
0.125 kHz	0.1	10.9
0.25 kHz	0.1	25.4
0.5 kHz	0.9	31.9
1 kHz	0.4	31.3
2 kHz	0.4	19.0
4 kHz	0.5	14.1
8 kHz	0.5	12.9
16 kHz	0.1	9.5
Standard deviations		
0.125 kHz	0.5	8.6
0.25 kHz	0.5	14.5
0.5 kHz	1.8	52.4
1 kHz	1.3	55.2
2 kHz	1.3	18.3
4 kHz	1.5	8.2
8 kHz	1.2	7.6
16 kHz	0.5	3.4

Source III Reverberant Impulses
155 dB peak SPL - 1X

Total sensory cell losses over octave band frequencies

	Inner hair cells	1st row outer hair cells	2nd row outer hair cells	3rd row outer hair cells	Comb. outer hair cells	Inner pillar cells	Outer pillar cells
Chinchilla 1334							
0.125 kHz	0	0	1	0	1	0	0
0.25 kHz	0	0	2	12	14	0	0
0.5 kHz	1	0	5	6	11	0	0
1 kHz	0	1	22	9	32	0	0
2 kHz	0	0	49	1	50	0	0
4 kHz	0	0	19	6	25	0	0
8 kHz	0	1	1	0	2	0	0
16 kHz	0	1	5	1	7	0	0
TOTALS	1	3	104	35	142	0	0
Chinchilla 1341							
0.125 kHz	2	0	3	1	4	0	0
0.25 kHz	0	2	12	24	38	0	1
0.5 kHz	2	4	5	14	23	0	0
1 kHz	0	3	9	6	18	0	0
2 kHz	0	1	1	4	6	0	3
4 kHz	3	2	7	13	22	0	2
8 kHz	0	3	7	22	32	0	1
16 kHz	0	0	4	3	7	0	0
TOTALS	7	15	48	87	150	0	7
Chinchilla 1354							
0.125 kHz	0	1	3	13	17	0	0
0.25 kHz	0	13	6	25	44	0	0
0.5 kHz	7	163	11	43	217	0	3
1 kHz	0	125	59	41	225	0	3
2 kHz	0	12	21	20	53	0	0
4 kHz	0	4	4	15	23	0	1
8 kHz	3	3	8	12	23	1	1
16 kHz	0	1	2	3	6	0	0
TOTALS	10	322	114	172	608	1	8

Source III Reverberant Impulses
155 dB peak SPL - 1X

Total sensory cell losses over octave band frequencies

	Inner hair cells	1st row outer hair cells	2nd row outer hair cells	3rd row outer hair cells	Comb. outer hair cells	Inner pillar cells	Outer pillar cells
Chinchilla 1356							
0.125 kHz	0	1	2	8	11	0	0
0.25 kHz	0	1	8	43	52	0	0
0.5 kHz	1	4	5	12	21	0	0
1 kHz	0	9	21	14	44	0	0
2 kHz	0	7	4	7	18	0	0
4 kHz	5	3	5	0	8	0	0
8 kHz	4	3	4	3	10	0	1
16 kHz	0	0	3	3	6	0	0
TOTALS	10	28	52	90	170	0	1
Chinchilla 1363							
0.125 kHz	0	0	2	4	6	0	1
0.25 kHz	0	0	5	28	33	0	1
0.5 kHz	0	2	7	22	31	0	1
1 kHz	0	2	9	9	20	0	0
2 kHz	0	1	9	7	17	0	0
4 kHz	0	3	5	4	12	0	2
8 kHz	1	3	5	6	14	0	1
16 kHz	0	1	4	4	9	0	0
TOTALS	1	12	46	84	142	0	6
Chinchilla 1368							
0.125 kHz	0	0	6	17	23	0	0
0.25 kHz	2	2	11	19	32	0	2
0.5 kHz	2	10	12	26	48	2	9
1 kHz	0	18	14	12	44	0	11
2 kHz	0	30	21	3	54	0	21
4 kHz	0	1	3	6	10	0	1
8 kHz	0	0	1	6	7	0	0
16 kHz	0	2	5	5	12	0	0
TOTALS	4	63	73	94	230	2	44

Source III Reverberant Impulses
155 dB peak SPL - 1X

Total sensory cell losses over octave band frequencies

	Inner hair cells	1st row outer hair cells	2nd row outer hair cells	3rd row outer hair cells	Comb. outer hair cells	Inner pillar cells	Outer pillar cells
Chinchilla 1385							
0.125 kHz	0	0	4	12	16	0	0
0.25 kHz	0	4	3	25	32	0	0
0.5 kHz	0	2	2	10	14	0	1
1 kHz	1	1	5	4	10	0	5
2 kHz	0	1	0	4	5	0	0
4 kHz	0	1	0	11	12	0	0
8 kHz	0	2	4	4	10	0	2
16 kHz	0	1	1	8	10	0	0
TOTALS	1	12	19	78	109	0	8
Chinchilla 1390							
0.125 kHz	0	1	3	7	11	0	0
0.25 kHz	0	2	5	5	12	0	0
0.5 kHz	1	0	4	2	6	0	1
1 kHz	0	0	4	5	9	0	0
2 kHz	5	1	0	3	4	0	0
4 kHz	0	1	3	3	7	0	0
8 kHz	0	3	5	6	14	0	0
16 kHz	0	1	6	3	10	0	0
TOTALS	6	9	30	34	73	0	1
Chinchilla 1402							
0.125 kHz	0	0	0	0	0	0	0
0.25 kHz	0	0	2	8	10	0	0
0.5 kHz	0	2	5	7	14	0	0
1 kHz	0	1	6	6	13	0	2
2 kHz	0	3	6	3	12	0	1
4 kHz	0	3	7	3	13	0	3
8 kHz	0	4	9	4	17	0	0
16 kHz	2	2	1	4	7	0	0
TOTALS	2	15	36	35	86	0	6

Source III Reverberant Impulses
155 dB peak SPL - 1X

Total sensory cell losses over octave band frequencies

	Inner hair cells	1st row outer hair cells	2nd row outer hair cells	3rd row outer hair cells	Comb. outer hair cells	Inner pillar cells	Outer pillar cells
Chinchilla 1407							
0.125 kHz	0	1	2	2	5	0	0
0.25 kHz	0	0	2	1	3	0	0
0.5 kHz	0	0	14	7	21	0	0
1 kHz	0	3	0	1	4	0	0
2 kHz	0	1	5	1	7	0	0
4 kHz	0	0	4	3	7	0	0
8 kHz	0	3	4	9	16	0	0
16 kHz	0	7	6	5	18	0	0
TOTALS	0	15	37	29	81	0	0
Chinchilla 1408							
0.125 kHz	0	0	0	0	0	0	0
0.25 kHz	0	1	10	12	23	0	0
0.5 kHz	0	2	6	18	26	0	0
1 kHz	0	2	11	11	24	0	0
2 kHz	0	2	13	8	23	0	0
4 kHz	0	8	9	12	29	0	0
8 kHz	0	5	3	0	8	0	0
16 kHz	0	0	5	6	11	0	0
TOTALS	0	20	57	67	144	0	0
Chinchilla 1410							
0.125 kHz	0	0	4	8	12	0	0
0.25 kHz	0	0	2	9	11	0	0
0.5 kHz	0	0	1	0	1	0	0
1 kHz	5	0	2	6	8	0	0
2 kHz	0	1	3	2	6	0	0
4 kHz	0	1	2	0	3	0	0
8 kHz	0	3	8	7	18	0	0
16 kHz	0	0	6	0	6	0	0
TOTALS	5	5	28	32	65	0	0

Source III Reverberant Impulses
155 dB peak SPL - 1X

Total sensory cell losses over octave band frequencies

	Inner hair cells	1st row outer hair cells	2nd row outer hair cells	3rd row outer hair cells	Comb. outer hair cells	Inner pillar cells	Outer pillar cells
Chinchilla 1434							
0.125 kHz	0	0	5	13	18	0	0
0.25 kHz	0	1	1	34	36	0	0
0.5 kHz	0	0	2	12	14	0	0
1 kHz	0	2	0	3	5	0	0
2 kHz	0	0	2	0	2	0	0
4 kHz	0	0	4	5	9	0	0
8 kHz	0	0	5	0	5	0	0
16 kHz	0	1	5	4	10	0	0
TOTALS	0	4	24	71	99	0	0
Chinchilla 1440							
0.125 kHz	0	1	8	20	29	0	0
0.25 kHz	0	2	0	28	30	0	0
0.5 kHz	0	0	1	8	9	0	0
1 kHz	0	2	2	6	10	0	1
2 kHz	1	4	3	3	10	3	3
4 kHz	0	0	2	6	8	0	0
8 kHz	0	3	0	5	8	0	0
16 kHz	0	1	11	2	14	0	0
TOTALS	1	13	27	78	118	3	4
Chinchilla 1441							
0.125 kHz	0	0	6	4	10	0	0
0.25 kHz	0	2	3	6	11	0	0
0.5 kHz	0	3	6	14	23	1	1
1 kHz	0	0	0	4	4	0	0
2 kHz	0	1	8	9	18	0	0
4 kHz	0	5	11	8	24	1	0
8 kHz	0	0	5	5	10	0	0
16 kHz	0	6	4	0	10	0	0
TOTALS	0	17	43	50	110	2	1

Source III Reverberant Impulses
155 dB peak SPL - 1X

Total sensory cell losses over octave band frequencies

	Inner hair cells	1st row outer hair cells	2nd row outer hair cells	3rd row outer hair cells	Comb. outer hair cells	Inner pillar cells	Outer pillar cells
Group means							
0.125 kHz	0.1	0.3	3.3	7.3	10.9	0.0	0.1
0.25 kHz	0.1	2.0	4.8	18.6	25.4	0.0	0.3
0.5 kHz	0.9	12.8	5.7	13.4	31.9	0.2	1.1
1 kHz	0.4	11.3	10.9	9.1	31.3	0.0	1.5
2 kHz	0.4	4.3	9.7	5.0	19.0	0.2	1.9
4 kHz	0.5	2.1	5.7	6.3	14.1	0.1	0.6
8 kHz	0.5	2.4	4.6	5.9	12.9	0.1	0.4
16 kHz	0.1	1.6	4.5	3.4	9.5	0.0	0.0
TOTALS	3.2	36.9	49.2	69.1	155.1	0.5	5.7
Group standard deviations							
0.125 kHz	0.5	0.5	2.3	6.5	8.6	0.0	0.3
0.25 kHz	0.5	3.3	3.8	12.1	14.5	0.0	0.6
0.5 kHz	1.8	41.6	3.9	10.8	52.4	0.6	2.3
1 kHz	1.3	31.8	15.1	9.5	55.2	0.0	3.0
2 kHz	1.3	7.8	12.8	4.9	18.3	0.8	5.4
4 kHz	1.5	2.3	4.7	4.6	8.2	0.3	1.0
8 kHz	1.2	1.5	2.7	5.5	7.6	0.3	0.6
16 kHz	0.5	2.1	2.4	2.2	3.4	0.0	0.0
TOTALS	3.6	80.2	28.1	37.1	132.4	1.0	11.1
Group standard errors							
0.125 kHz	0.1	0.1	0.6	1.7	2.2	0.0	0.1
0.25 kHz	0.1	0.8	1.0	3.1	3.8	0.0	0.2
0.5 kHz	0.5	10.8	1.0	2.8	13.5	0.1	0.6
1 kHz	0.3	8.2	3.9	2.5	14.3	0.0	0.8
2 kHz	0.3	2.0	3.3	1.3	4.7	0.2	1.4
4 kHz	0.4	0.6	1.2	1.2	2.1	0.1	0.3
8 kHz	0.3	0.4	0.7	1.4	2.0	0.1	0.2
16 kHz	0.1	0.5	0.6	0.6	0.9	0.0	0.0
TOTALS	0.9	20.7	7.3	9.6	34.2	0.3	2.9

Source III Reverberant Impulses
155 dB peak SPL - 1X

Percent sensory cell losses over octave band frequencies

	Inner hair cells	1st row outer hair cells	2nd row outer hair cells	3rd row outer hair cells	Comb. outer hair cells	Inner pillar cells	Outer pillar cells
Chinchilla 1334							
0.125 kHz	0.0	0.0	0.6	0.0	0.2	0.0	0.0
0.25 kHz	0.0	0.0	0.7	4.1	1.6	0.0	0.0
0.5 kHz	0.5	0.0	1.7	2.1	1.3	0.0	0.0
1 kHz	0.0	0.4	8.0	3.3	3.9	0.0	0.0
2 kHz	0.0	0.0	17.4	0.4	5.9	0.0	0.0
4 kHz	0.0	0.0	6.8	2.1	3.0	0.0	0.0
8 kHz	0.0	0.4	0.4	0.0	0.3	0.0	0.0
16 kHz	0.0	0.4	2.0	0.4	0.9	0.0	0.0
Chinchilla 1341							
0.125 kHz	1.4	0.0	1.6	0.5	0.7	0.0	0.0
0.25 kHz	0.0	0.6	3.6	7.2	3.8	0.0	0.3
0.5 kHz	0.8	1.2	1.5	4.2	2.3	0.0	0.0
1 kHz	0.0	0.9	2.8	1.9	1.9	0.0	0.0
2 kHz	0.0	0.3	0.3	1.2	0.6	0.0	0.9
4 kHz	1.2	0.6	2.2	4.0	2.3	0.0	0.6
8 kHz	0.0	0.9	2.2	6.8	3.3	0.0	0.3
16 kHz	0.0	0.0	1.4	1.0	0.8	0.0	0.0
Chinchilla 1354							
0.125 kHz	0.0	0.5	1.6	6.8	3.0	0.0	0.0
0.25 kHz	0.0	3.9	1.8	7.5	4.4	0.0	0.0
0.5 kHz	2.8	49.1	3.3	13.0	21.8	0.0	0.9
1 kHz	0.0	39.7	18.7	13.0	23.8	0.0	1.0
2 kHz	0.0	3.7	6.5	6.2	5.5	0.0	0.0
4 kHz	0.0	1.2	1.2	4.7	2.4	0.0	0.3
8 kHz	1.2	0.9	2.5	3.7	2.4	0.2	0.3
16 kHz	0.0	0.3	0.7	1.0	0.7	0.0	0.0
Chinchilla 1356							
0.125 kHz	0.0	0.6	1.2	4.7	2.2	0.0	0.0
0.25 kHz	0.0	0.3	2.6	14.2	5.7	0.0	0.0
0.5 kHz	0.4	1.3	1.7	4.0	2.3	0.0	0.0
1 kHz	0.0	3.1	7.3	4.9	5.1	0.0	0.0
2 kHz	0.0	2.4	1.4	2.4	2.1	0.0	0.0
4 kHz	2.2	1.0	1.7	0.0	0.9	0.0	0.0
8 kHz	1.7	1.0	1.4	1.0	1.1	0.0	0.3
16 kHz	0.0	0.0	1.1	1.1	0.7	0.0	0.0

Source III Reverberant Impulses
155 dB peak SPL - 1X

Percent sensory cell losses over octave band frequencies

	Inner hair cells	1st row outer hair cells	2nd row outer hair cells	3rd row outer hair cells	Comb. outer hair cells	Inner pillar cells	Outer pillar cells
Chinchilla 1363							
0.125 kHz	.0	0.0	1.1	2.1	1.1	0.0	0.5
0.25 kHz	0.0	0.0	1.5	8.4	3.3	0.0	0.3
0.5 kHz	0.0	0.6	2.1	6.6	3.1	0.0	0.3
1 kHz	0.0	0.6	2.9	2.9	2.1	0.0	0.0
2 kHz	0.0	0.3	2.8	2.2	1.8	0.0	0.0
4 kHz	0.0	0.9	1.6	1.2	1.2	0.0	0.6
8 kHz	0.4	0.9	1.6	1.9	1.5	0.0	0.3
16 kHz	0.0	0.3	1.4	1.4	1.0	0.0	0.0
Chinchilla 1368							
0.125 kHz	0.0	0.0	3.2	9.0	4.1	0.0	0.0
0.25 kHz	0.8	0.6	3.3	5.7	3.2	0.0	0.6
0.5 kHz	0.8	3.0	3.6	7.9	4.8	0.4	2.7
1 kHz	0.0	5.7	4.5	3.8	4.7	0.0	3.5
2 kHz	0.0	9.3	6.5	0.9	5.6	0.0	6.5
4 kHz	0.0	0.3	0.9	1.9	1.0	0.0	0.3
8 kHz	0.0	0.0	0.3	1.9	0.7	0.0	0.0
16 kHz	0.0	0.7	1.7	1.7	1.4	0.0	0.0
Chinchilla 1385							
0.125 kHz	0.0	0.0	2.2	6.5	2.9	0.0	0.0
0.25 kHz	0.0	1.2	0.9	7.7	3.3	0.0	0.0
0.5 kHz	0.0	0.6	0.6	3.1	1.4	0.0	0.3
1 kHz	0.4	0.3	1.6	1.3	1.1	0.0	1.6
2 kHz	0.0	0.3	0.0	1.3	0.3	0.0	0.0
4 kHz	0.0	0.3	0.0	3.5	1.3	0.0	0.0
8 kHz	0.0	0.6	1.3	1.3	1.1	0.0	0.6
16 kHz	0.0	0.4	0.4	2.8	1.2	0.0	0.0
Chinchilla 1390							
0.125 kHz	0.0	0.5	1.6	3.8	2.0	0.0	0.0
0.25 kHz	0.0	0.6	1.5	1.5	1.2	0.0	0.0
0.5 kHz	0.4	0.0	1.2	0.6	0.6	0.0	0.3
1 kHz	0.0	0.0	1.3	1.6	1.0	0.0	0.0
2 kHz	2.1	0.3	0.0	0.9	0.4	0.0	0.0
4 kHz	0.0	0.3	0.9	0.9	0.7	0.0	0.0
8 kHz	0.0	0.9	1.6	1.9	1.5	0.0	0.0
16 kHz	0.0	0.4	2.1	1.1	1.2	0.0	0.0

Source III Reverberant Impulses
155 dB peak SPL - 1X

Percent sensory cell losses over octave band frequencies

	Inner hair cells	1st row outer hair cells	2nd row outer hair cells	3rd row outer hair cells	Comb. outer hair cells	Inner pillar cells	Outer pillar cells
Chinchilla 1402							
0.125 kHz	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.25 kHz	0.0	0.0	0.6	2.4	1.0	0.0	0.0
0.5 kHz	0.0	0.6	1.5	2.1	1.4	0.0	0.0
1 kHz	0.0	0.3	1.9	1.9	1.4	0.0	0.6
2 kHz	0.0	0.9	1.9	0.9	1.2	0.0	0.3
4 kHz	0.0	0.9	2.2	0.9	1.3	0.0	0.9
8 kHz	0.0	1.2	2.8	1.2	1.7	0.0	0.0
16 kHz	0.9	0.7	0.3	1.4	0.8	0.0	0.0
Chinchilla 1407							
0.125 kHz	0.0	0.5	1.1	1.1	0.9	0.0	0.0
0.25 kHz	0.0	0.0	0.6	0.3	0.3	0.0	0.0
0.5 kHz	0.0	0.0	4.2	2.1	2.1	0.0	0.0
1 kHz	0.0	1.0	0.0	0.3	0.4	0.0	0 0
2 kHz	0.0	0.3	1.5	0.3	0.7	0.0	0.0
4 kHz	0.0	0.0	1.2	0.9	0.7	0.0	0.0
8 kHz	0.0	0.9	1.2	2.8	1.6	0.0	0.0
16 kHz	0.0	2.4	2.1	1.7	2.1	0.0	0.0
Chinchilla 1408							
0.125 kHz	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.25 kHz	0.0	0.3	3.2	3.9	2.5	0.0	0.0
0.5 kHz	0.0	0.6	1.9	5.8	2.8	0.0	0.0
1 kHz	0.0	0.7	3.7	3.7	2.7	0.0	0.0
2 kHz	0.0	0.7	4.3	2.7	2.6	0.0	0.0
4 kHz	0.0	2.7	3.0	4.0	3.2	0.0	0.0
8 kHz	0.0	1.7	1.0	0.0	0.9	0.0	0.0
16 kHz	0.0	0.0	1.9	2.2	1.4	0.0	0.0
Chinchilla 1410							
0.125 kHz	0.0	0.0	2.2	4.4	2.2	0.0	0.0
0.25 kHz	0.0	0.0	0.6	2.8	1.1	0.0	0.0
0.5 kHz	0.0	0.0	0.3	0.0	0.1	0.0	0.0
1 kHz	2.1	0.0	0.7	2.0	0.9	0.0	0.0
2 kHz	0.0	0.3	1.0	0.6	0.6	0.0	0.0
4 kHz	0.0	0.3	0.6	0.0	0.3	0.0	0.0
8 kHz	0.0	1.0	2.6	2.3	2.0	0.0	0.0
16 kHz	0.0	0.0	2.2	0.0	0.7	0.0	0.0

Source III Reverberant Impulses
155 dB peak SPL - 1X

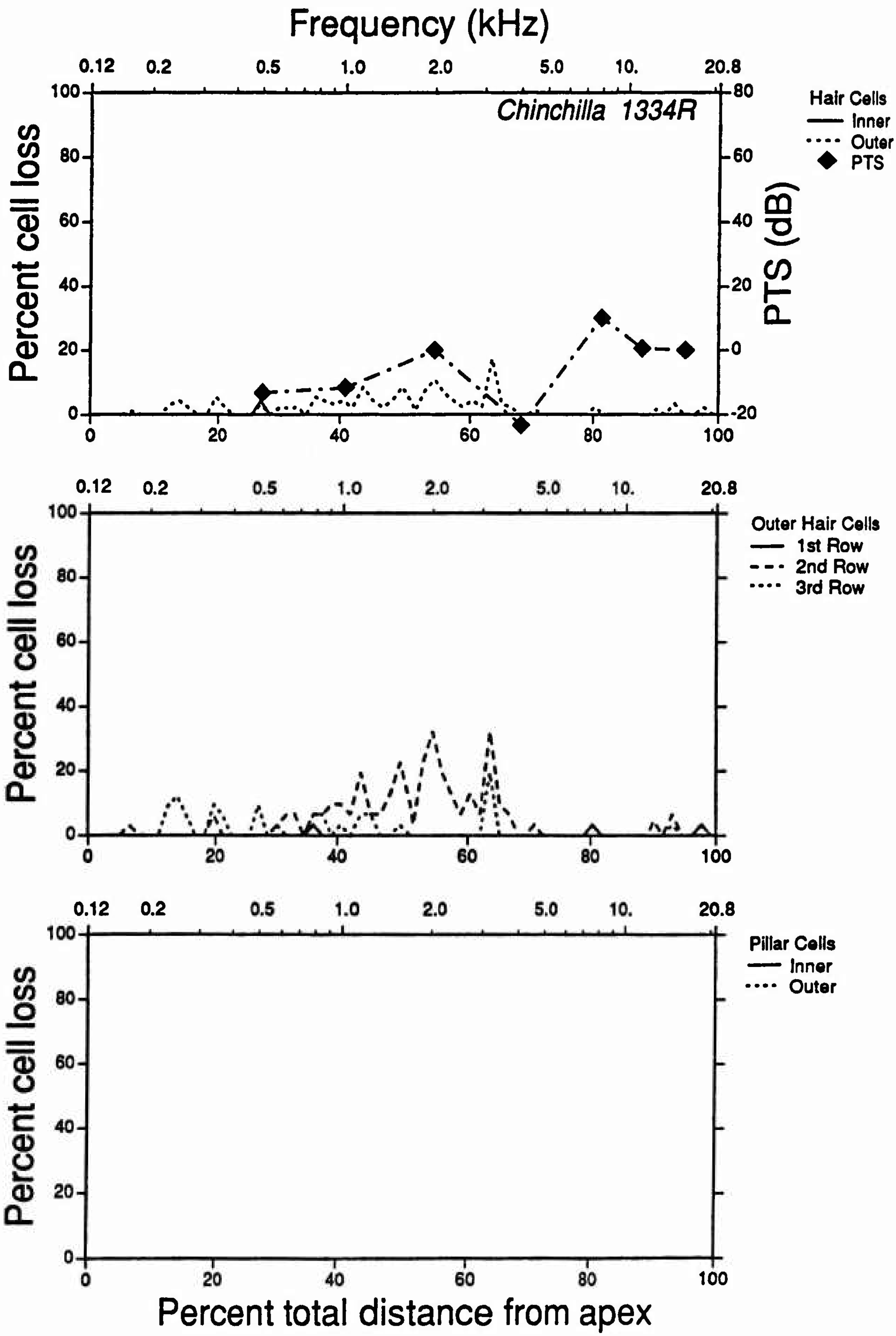
Percent sensory cell losses over octave band frequencies

	Inner hair cells	1st row outer hair cells	2nd row outer hair cells	3rd row outer hair cells	Comb. outer hair cells	Inner pillar cells	Outer pillar cells
Chinchilla 1434							
0.125 kHz	0.0	0.0	2.8	7.2	3.3	0.0	0.0
0.25 kHz	0.0	0.3	0.3	10.7	3.8	0.0	0.0
0.5 kHz	0.0	0.0	0.6	3.8	1.5	0.0	0.0
1 kHz	0.0	0.7	0.0	1.0	0.6	0.0	0.0
2 kHz	0.0	0.0	0.6	0.0	0.2	0.0	0.0
4 kHz	0.0	0.0	1.3	1.6	1.0	0.0	0.0
8 kHz	0.0	0.0	1.6	0.0	0.5	0.0	0.0
16 kHz	0.0	0.4	1.8	1.4	1.2	0.0	0.0
Chinchilla 1440							
0.125 kHz	0.0	0.5	4.1	10.2	4.9	0.0	0.0
0.25 kHz	0.0	0.6	0.0	8.0	2.9	0.0	0.0
0.5 kHz	0.0	0.0	0.3	2.3	0.9	0.0	0.0
1 kHz	0.0	0.6	0.6	1.8	1.0	0.0	0.3
2 kHz	0.4	1.2	0.9	0.9	1.0	0.6	0.9
4 kHz	0.0	0.0	0.6	1.8	0.8	0.0	0.0
8 kHz	0.0	0.9	0.0	1.5	0.8	0.0	0.0
16 kHz	0.0	0.3	3.7	0.7	1.6	0.0	0.0
Chinchilla 1441							
0.125 kHz	0.0	0.0	2.9	1.9	1.6	0.0	0.0
0.25 kHz	0.0	0.6	0.8	1.7	1.0	0.0	0.0
0.5 kHz	0.0	0.8	1.7	3.9	2.1	0.2	0.3
1 kHz	0.0	0.0	0.0	1.2	0.4	0.0	0.0
2 kHz	0.0	0.3	2.3	2.6	1.7	0.0	0.0
4 kHz	0.0	1.4	3.1	2.3	2.3	0.2	0.0
8 kHz	0.0	0.0	1.4	1.4	0.9	0.0	0.0
16 kHz	0.0	1.9	1.3	0.0	1.1	0.0	0.0

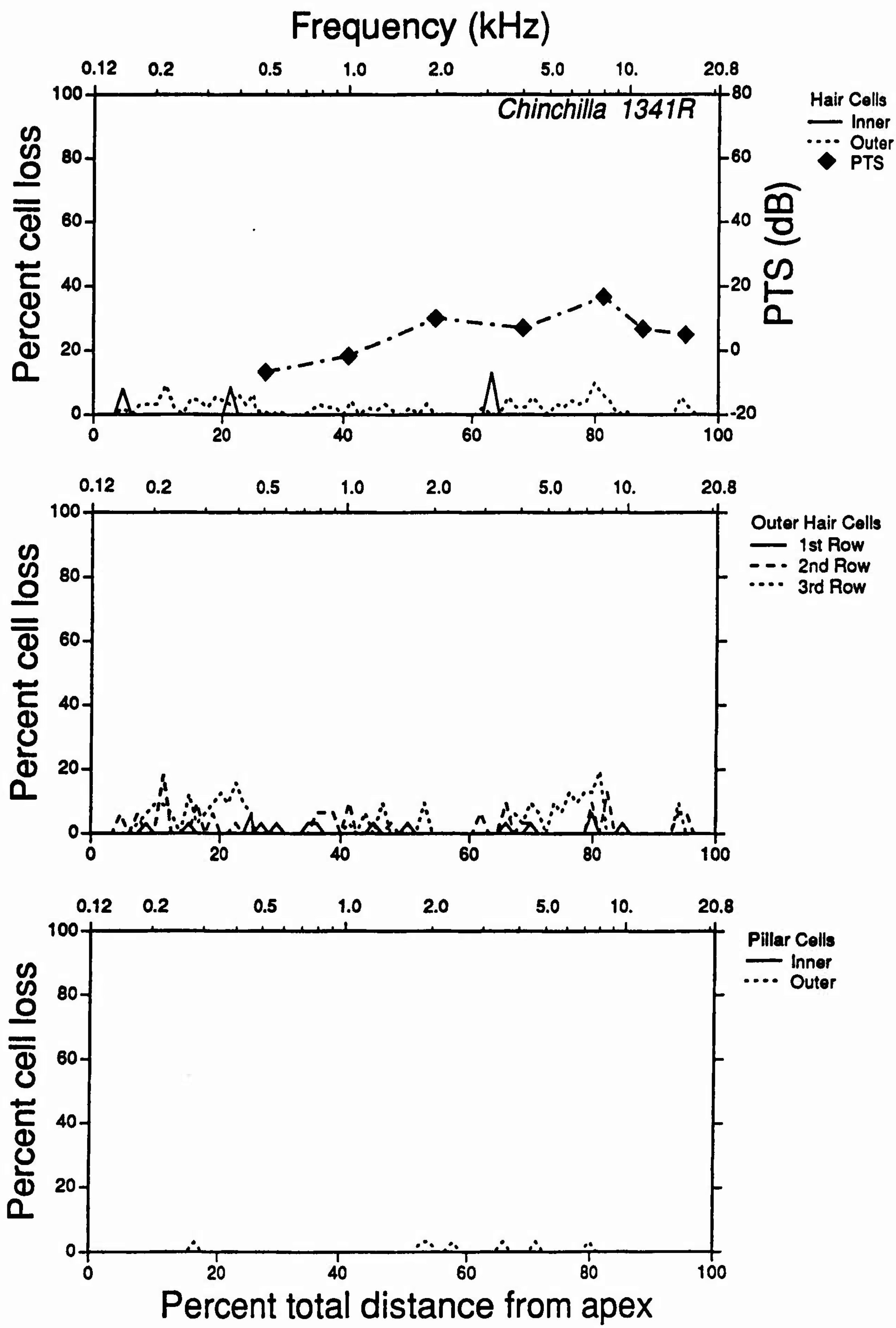
Source III Reverberant Impulses
155 dB peak SPL - 1X

Percent sensory cell losses over octave band frequencies

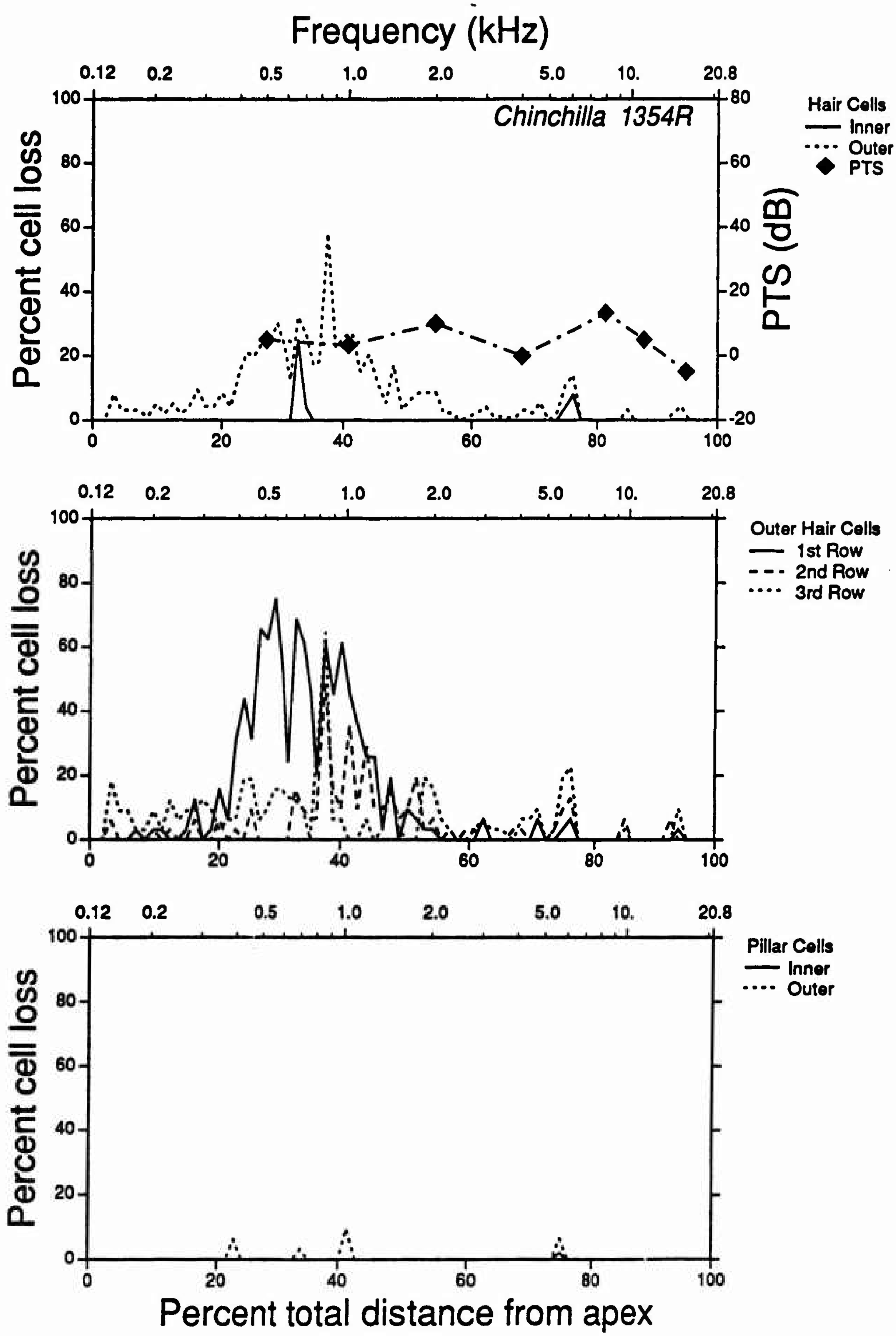
	Inner hair cells	1st row outer hair cells	2nd row outer hair cells	3rd row outer hair cells	Comb. outer hair cells	Inner pillar cells	Outer pillar cells
Group means							
0.125 kHz	0.09	0.17	1.75	3.88	1.93	0.00	0.03
0.25 kHz	0.05	0.60	1.47	5.74	2.60	0.00	0.08
0.5 kHz	0.38	3.85	1.75	4.10	3.23	0.04	0.32
1 kHz	0.17	3.60	3.60	2.97	3.39	0.00	0.47
2 kHz	0.17	1.35	3.16	1.57	2.03	0.04	0.57
4 kHz	0.23	0.66	1.82	1.99	1.49	0.01	0.18
8 kHz	0.22	0.75	1.46	1.85	1.35	0.01	0.12
16 kHz	0.06	0.55	1.61	1.19	1.12	0.00	0.00
Group standard deviations							
0.125 kHz	0.36	0.25	1.17	3.43	1.50	0.00	0.13
0.25 kHz	0.21	0.98	1.18	3.85	1.52	0.00	0.18
0.5 kHz	0.73	12.54	1.17	3.25	5.26	0.11	0.70
1 kHz	0.54	10.10	4.87	3.04	5.85	0.00	0.96
2 kHz	0.54	2.42	4.47	1.54	1.99	0.15	1.67
4 kHz	0.63	0.73	1.63	1.47	0.90	0.05	0.30
8 kHz	0.52	0.48	0.83	1.71	0.78	0.05	0.19
16 kHz	0.23	0.70	0.84	0.76	0.38	0.00	0.00
Group standard errors							
0.125 kHz	0.09	0.07	0.30	0.89	0.39	0.00	0.03
0.25 kHz	0.05	0.25	0.30	0.99	0.39	0.00	0.05
0.5 kHz	0.19	3.24	0.30	0.84	1.36	0.03	0.18
1 kHz	0.14	2.61	1.26	0.78	1.51	0.00	0.25
2 kHz	0.14	0.62	1.15	0.40	0.52	0.04	0.43
4 kHz	0.16	0.19	0.42	0.38	0.23	0.01	0.08
8 kHz	0.13	0.12	0.21	0.44	0.20	0.01	0.05
16 kHz	0.06	0.18	0.22	0.20	0.10	0.00	0.00



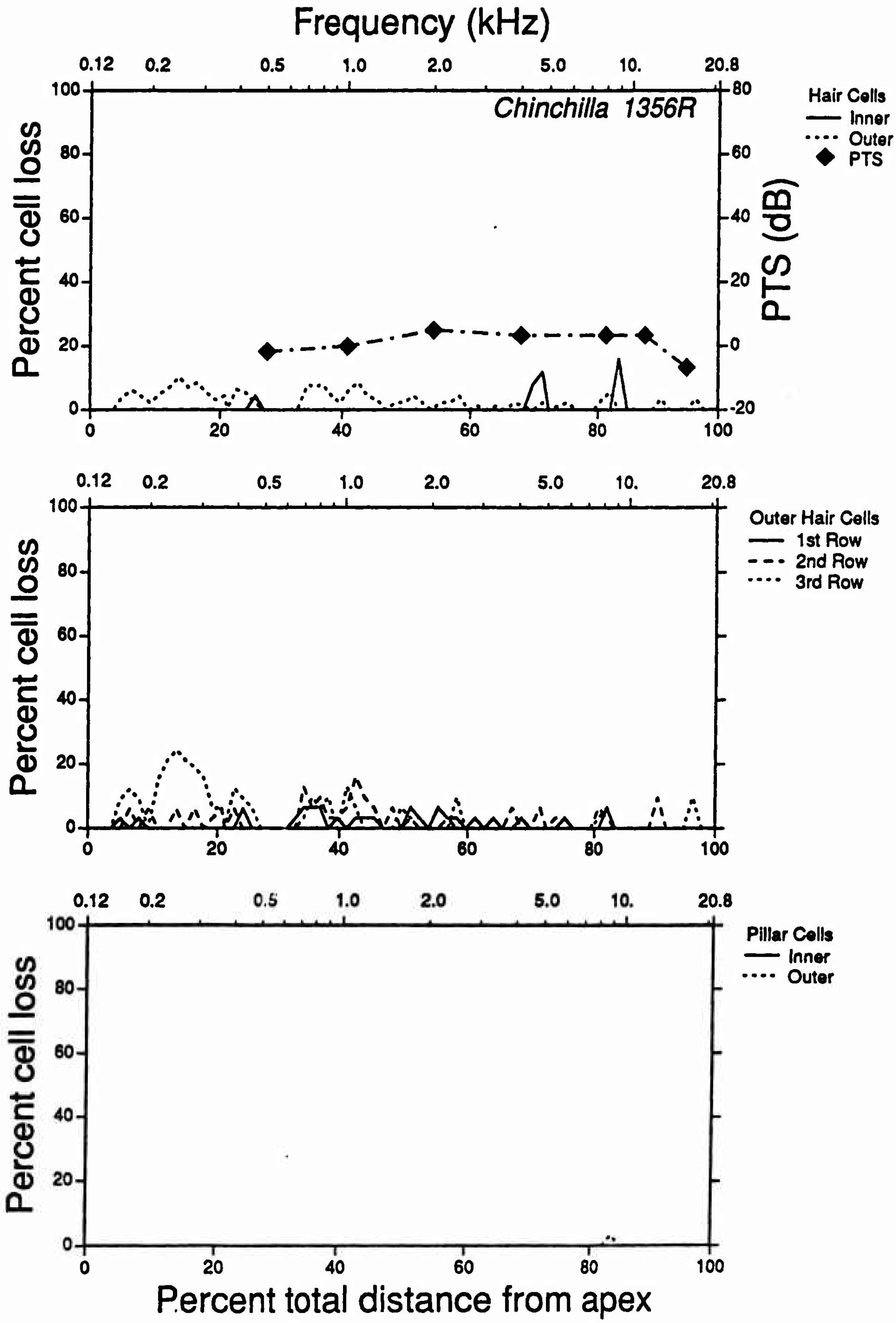
Frequency (kHz)
0.12
0.2
0.5
1.0
2.0
5.0
10.
20.8
Chinchilla 1334R
Percent cell loss
PTS (dB)
Hair Cells
Inner
Outer
PTS
Outer Hair Cells
1st Row
2nd Row
3rd Row
Pillar Cells
Inner
Outer
Percent total distance from apex

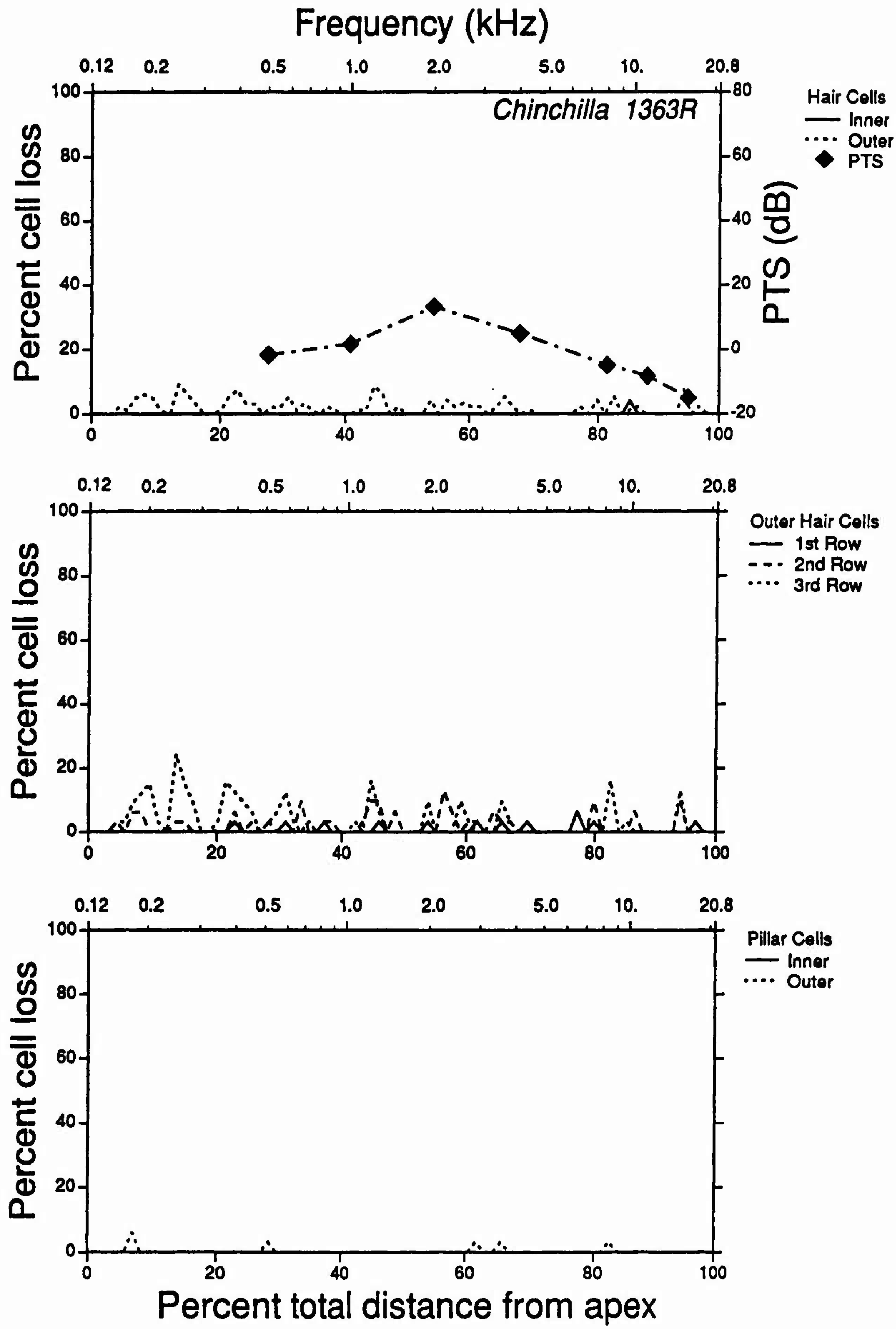


Frequency (kHz)
0.12
0.2
0.5
1.0
2.0
5.0
10.
20.8
Chinchilla 1341R
Percent cell loss
PTS (dB)
Hair Cells
Inner
Outer
PTS
Outer Hair Cells
1st Row
2nd Row
3rd Row
Pillar Cells
Inner
Outer
Percent total distance from apex

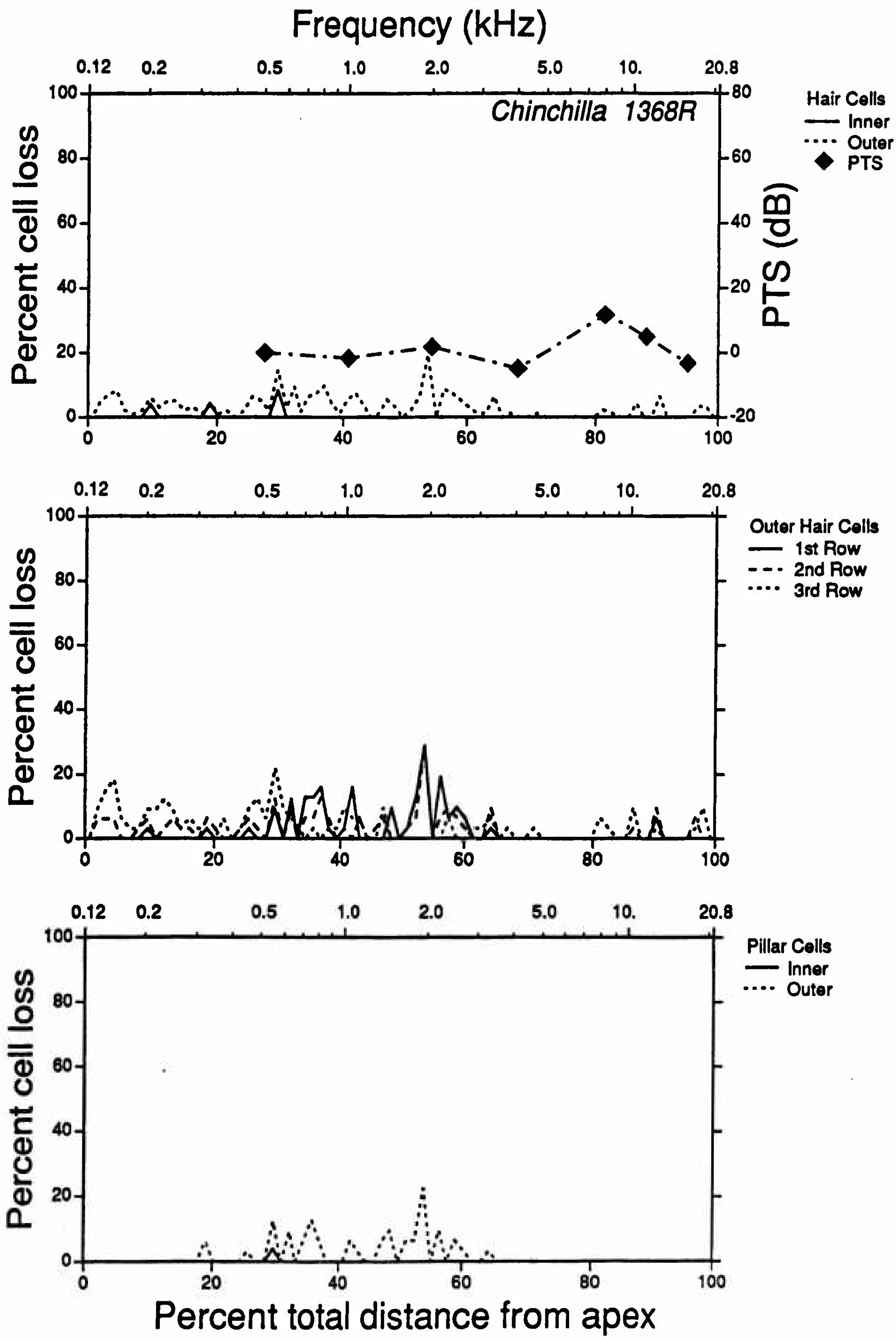


Frequency (kHz)
0.12 0.2 0.5 1.0 2.0 5.0 10. 20.8
Chinchilla 1354R
Percent cell loss
PTS (dB)
Hair Cells
Inner
Outer
PTS
Outer Hair Cells
1st Row
2nd Row
3rd Row
Pillar Cells
Inner
Outer
Percent total distance from apex

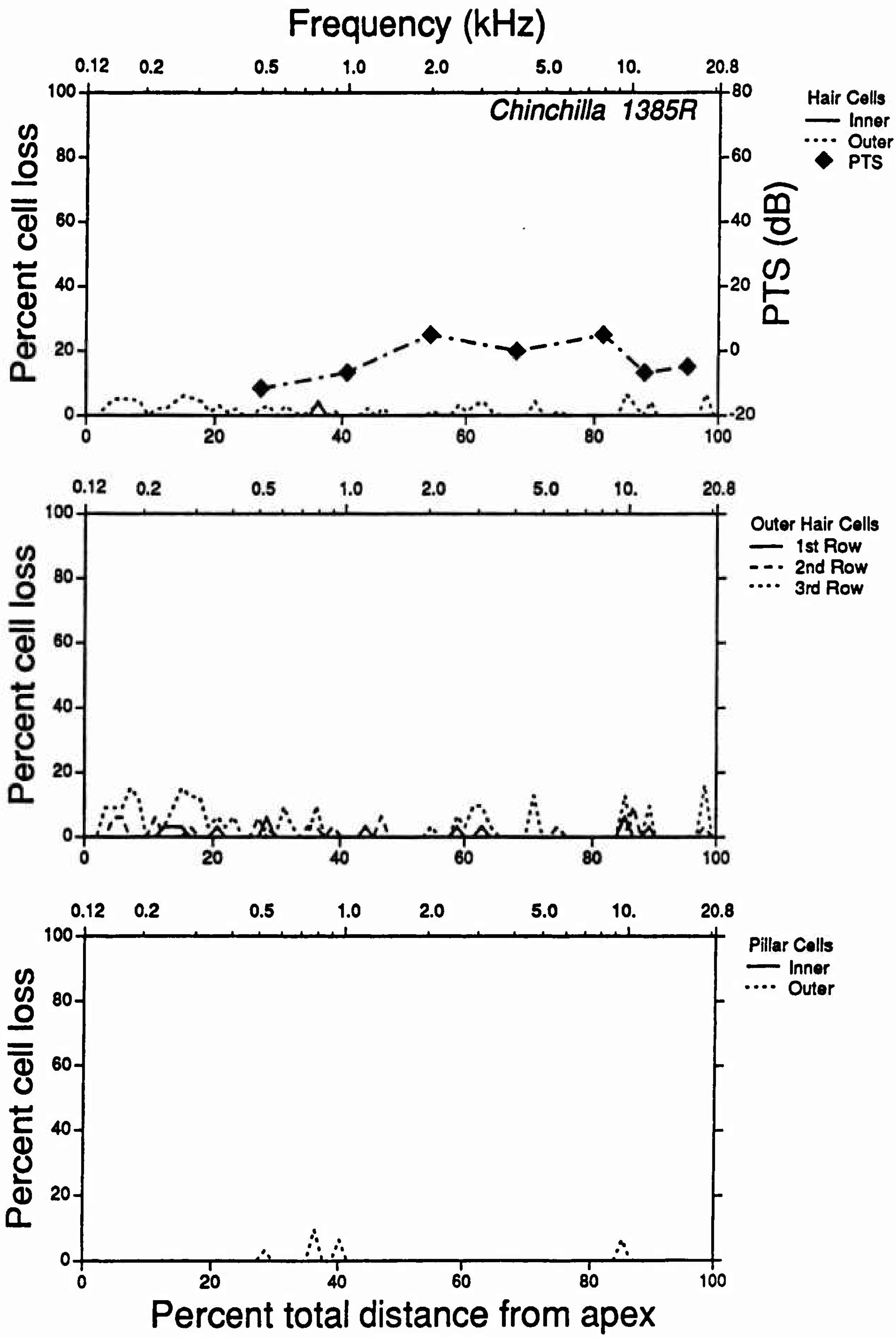

Frequency (kHz)
0.12 0.2 0.5 1.0 2.0 5.0 10. 20.8
Chinchilla 1356R
Percent cell loss
PTS (dB)
100 80 60 40 20 0
80 60 40 20 0 -20
0 20 40 60 80 100
Hair Cells
Inner
Outer
PTS
Outer Hair Cells
1st Row
2nd Row
3rd Row
Pillar Cells
Inner
Outer
Percent total distance from apex

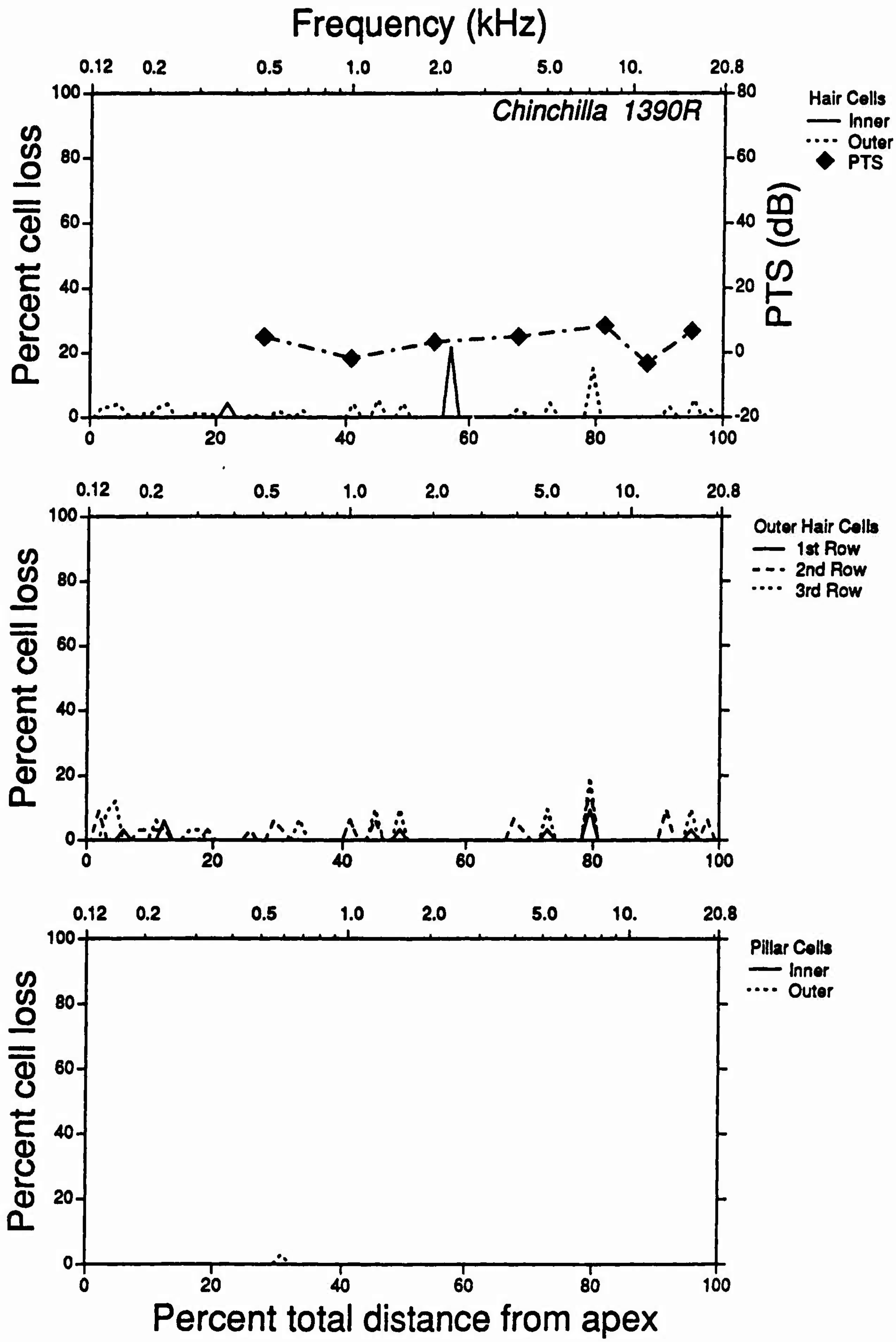


Frequency (kHz)
0.12
0.2
0.5
1.0
2.0
5.0
10.
20.8
Chinchilla 1363R
Percent cell loss
PTS (dB)
Hair Cells
Inner
Outer
PTS
Outer Hair Cells
1st Row
2nd Row
3rd Row
Pillar Cells
Inner
Outer
Percent total distance from apex

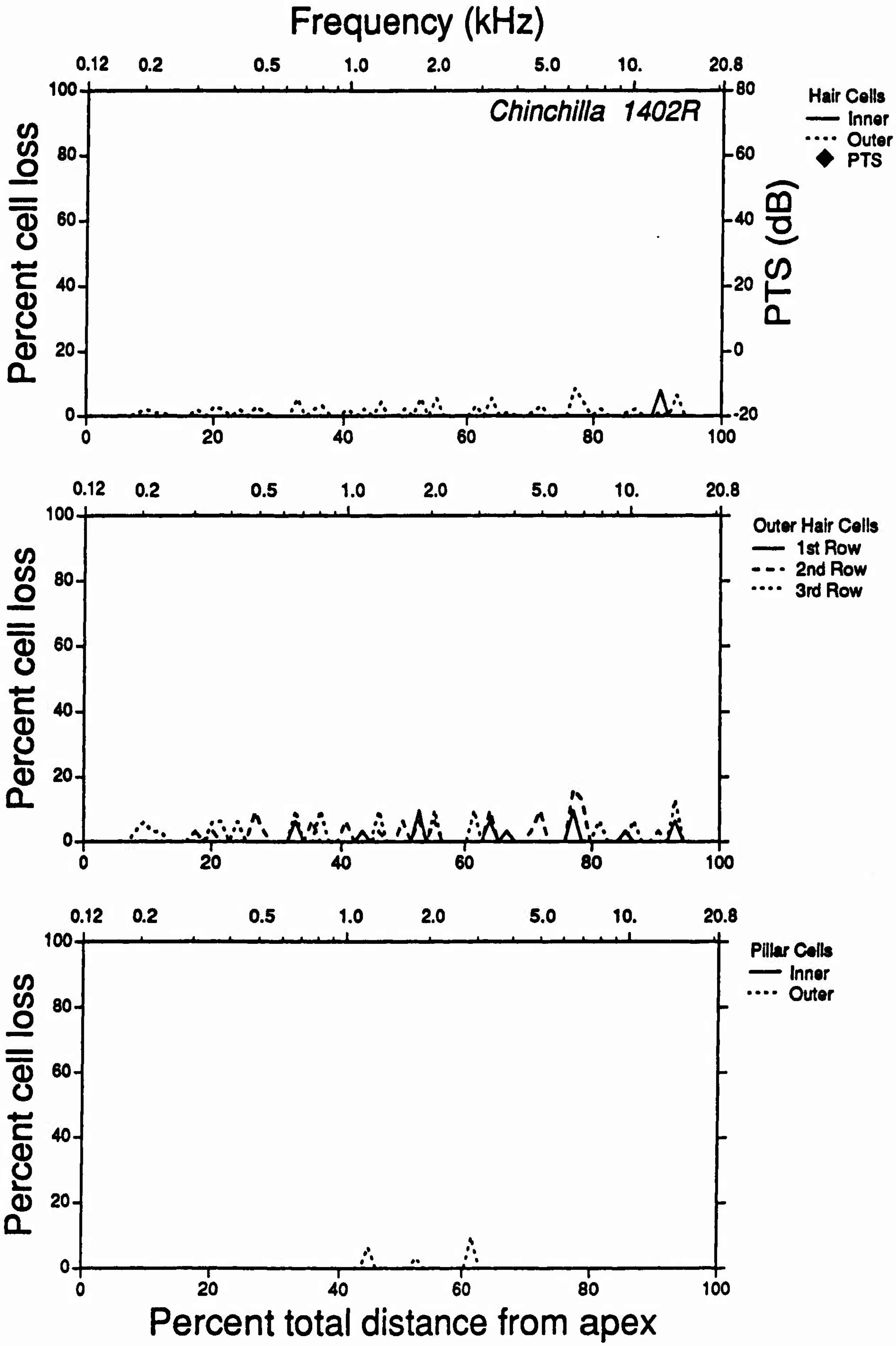


Frequency (kHz)
0.12
0.2
0.5
1.0
2.0
5.0
10.
20.8
Chinchilla 1368R
Percent cell loss
100
80
60
40
20
0
PTS (dB)
80
60
40
20
0
-20
Hair Cells
Inner
Outer
PTS
Outer Hair Cells
1st Row
2nd Row
3rd Row
Pillar Cells
Inner
Outer
0
20
40
60
80
100
Percent total distance from apex

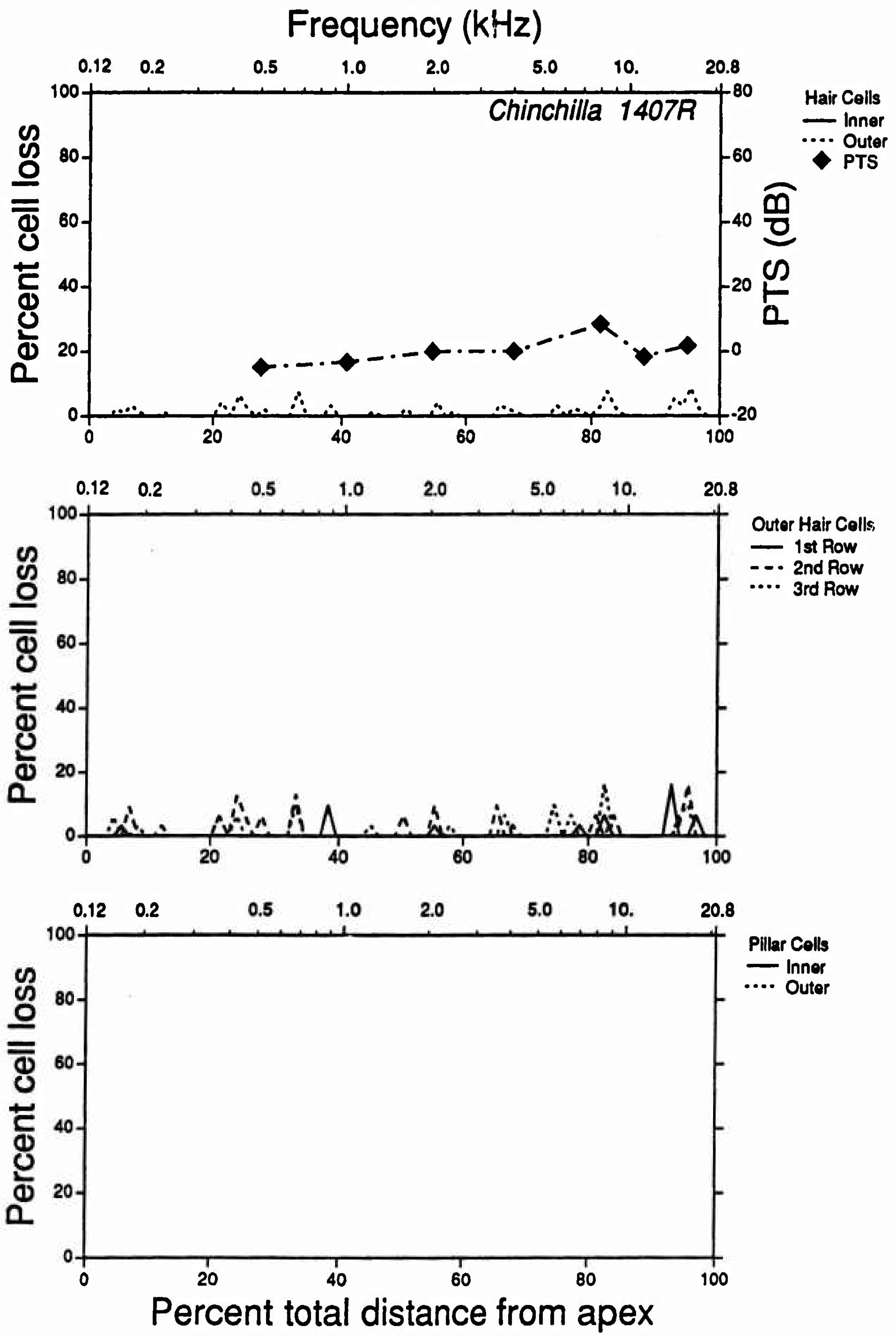

Frequency (kHz)
0.12
0.2
0.5
1.0
2.0
5.0
10.
20.8
Chinchilla 1385R
Percent cell loss
PTS (dB)
Hair Cells
Inner
Outer
PTS
Outer Hair Cells
1st Row
2nd Row
3rd Row
Pillar Cells
Inner
Outer
Percent total distance from apex

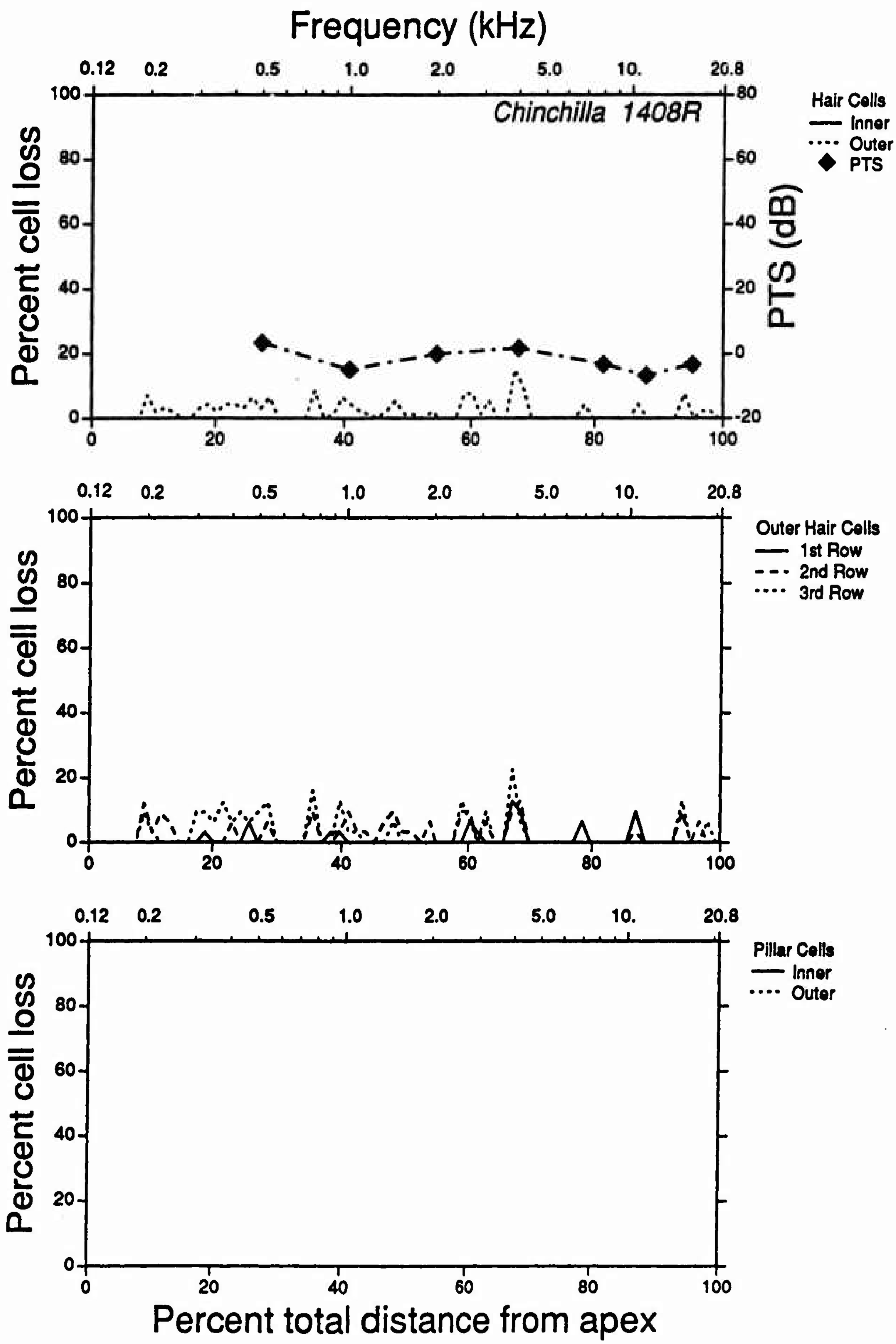


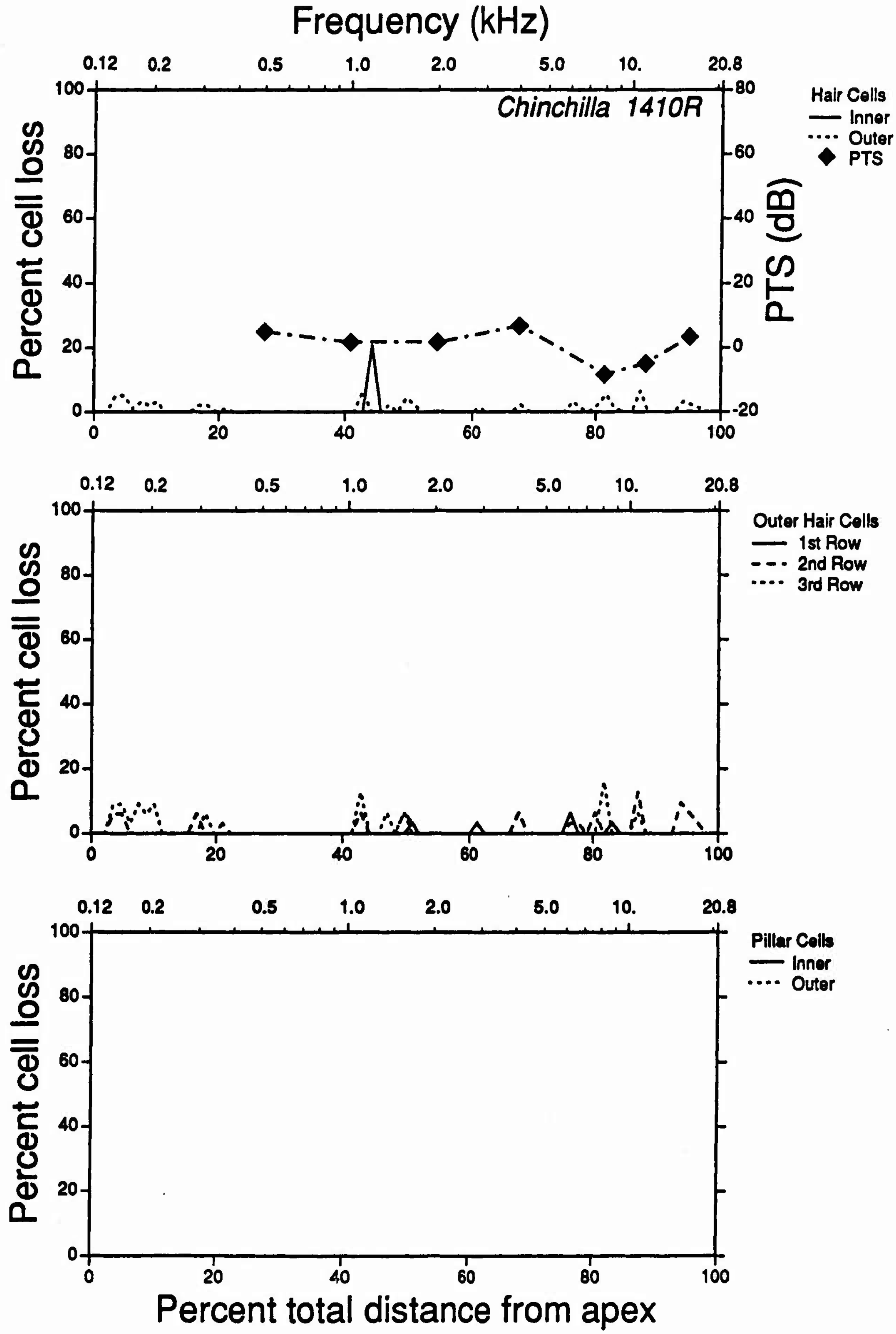
Frequency (kHz)
0.12
0.2
0.5
1.0
2.0
5.0
10.
20.8
Chinchilla 1390R
Percent cell loss
PTS (dB)
Hair Cells
Inner
Outer
PTS
Outer Hair Cells
1st Row
2nd Row
3rd Row
Pillar Cells
Inner
Outer
Percent total distance from apex



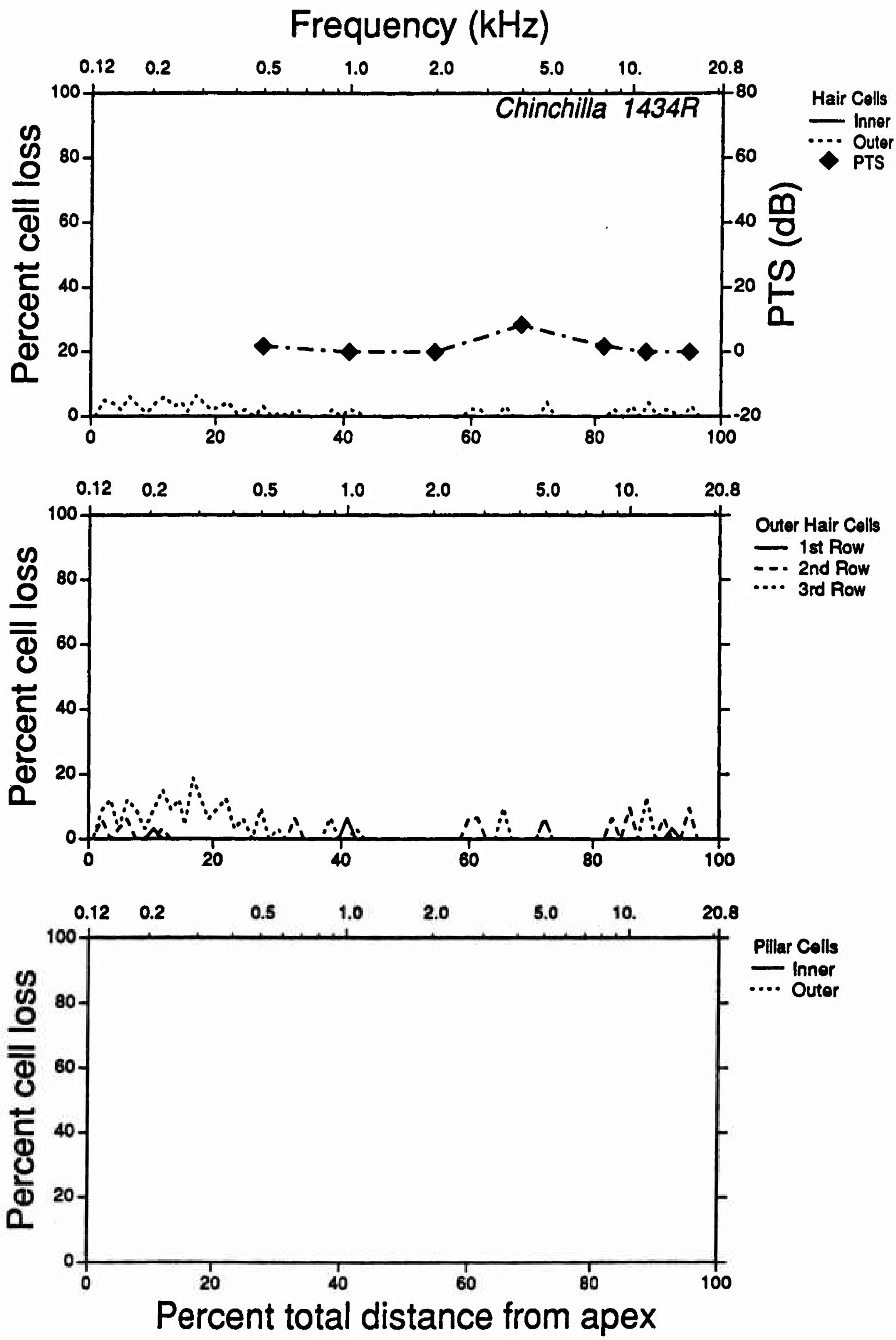
Frequency (kHz)
0.12 0.2 0.5 1.0 2.0 5.0 10. 20.8
Chinchilla 1402R
Percent cell loss
PTS (dB)
Hair Cells
Inner
Outer
PTS
Outer Hair Cells
1st Row
2nd Row
3rd Row
Pillar Cells
Inner
Outer
Percent total distance from apex


Frequency (kHz)
0.12
0.2
0.5
1.0
2.0
5.0
10.
20.8
Chinchilla 1407R
Percent cell loss
PTS (dB)
Hair Cells
Inner
Outer
PTS
Outer Hair Cells
1st Row
2nd Row
3rd Row
Pillar Cells
Inner
Outer
Percent total distance from apex

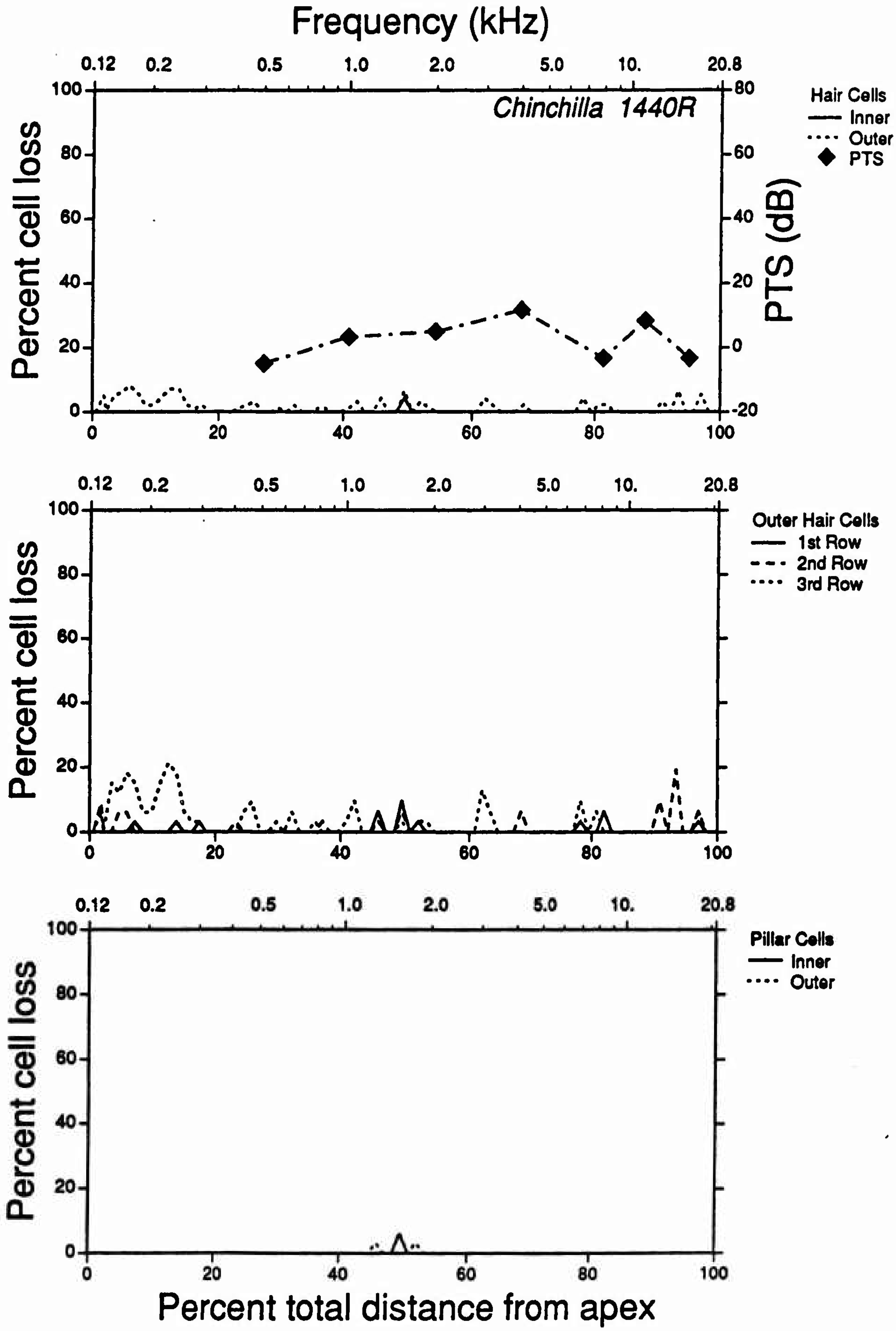

Frequency (kHz)
0.12
0.2
0.5
1.0
2.0
5.0
10.
20.8
Chinchilla 1408R
Percent cell loss
PTS (dB)
Hair Cells
Inner
Outer
PTS
Outer Hair Cells
1st Row
2nd Row
3rd Row
Pillar Cells
Inner
Outer
Percent total distance from apex



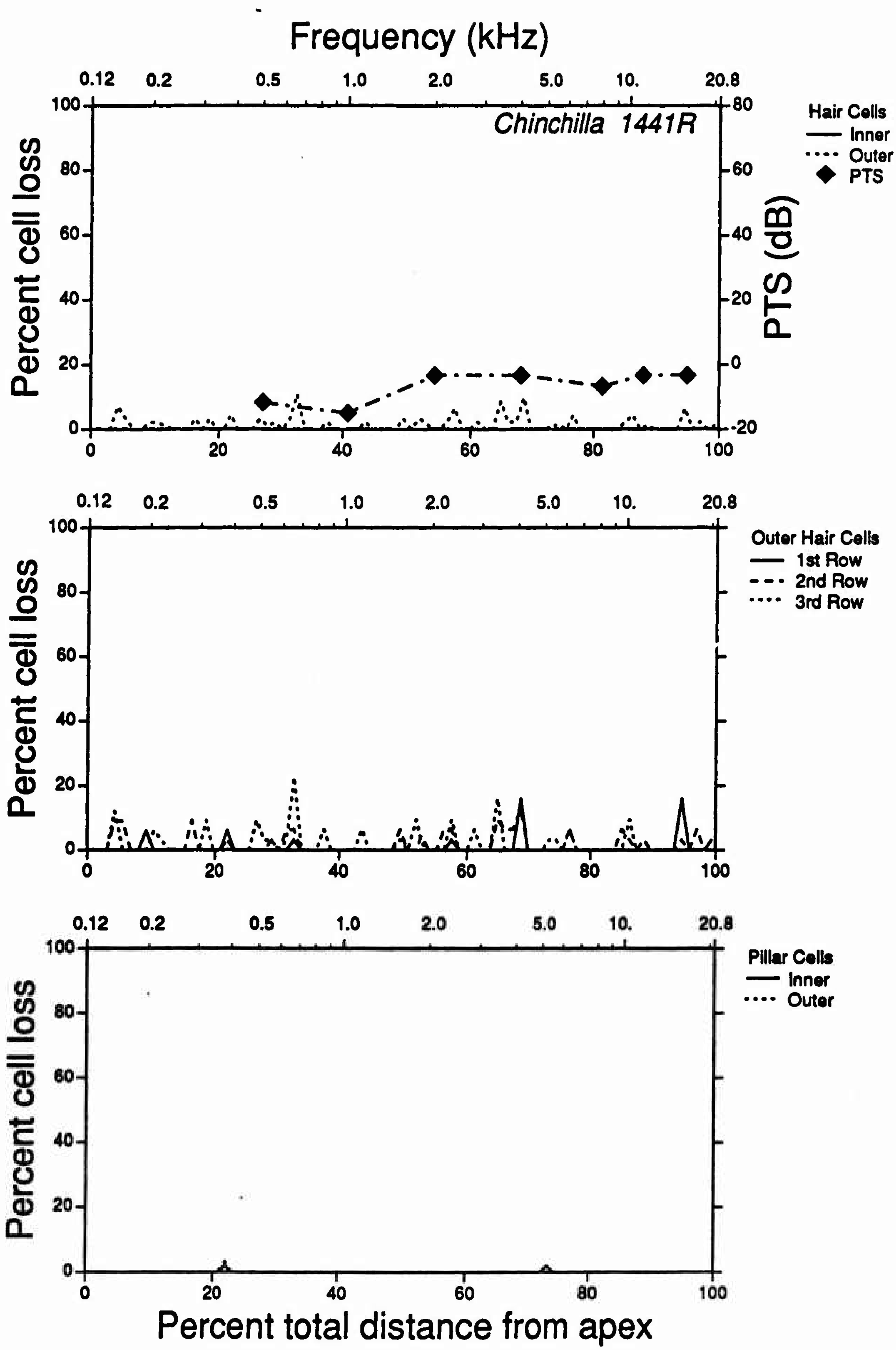
Frequency (kHz)
0.12
0.2
0.5
1.0
2.0
5.0
10.
20.8
Chinchilla 1410R
Percent cell loss
PTS (dB)
Hair Cells
Inner
Outer
PTS
Outer Hair Cells
1st Row
2nd Row
3rd Row
Pillar Cells
Inner
Outer
Percent total distance from apex



Frequency (kHz)
0.12
0.2
0.5
1.0
2.0
5.0
10.
20.8
Chinchilla 1434R
Percent cell loss
PTS (dB)
Hair Cells
Inner
Outer
PTS
Outer Hair Cells
1st Row
2nd Row
3rd Row
Pillar Cells
Inner
Outer
Percent total distance from apex



Frequency (kHz)
0.12
0.2
0.5
1.0
2.0
5.0
10.
20.8
Chinchilla 1440R
Percent cell loss
PTS (dB)
Hair Cells
Inner
Outer
PTS
Outer Hair Cells
1st Row
2nd Row
3rd Row
Pillar Cells
Inner
Outer
Percent total distance from apex



Frequency (kHz)
0.12
0.2
0.5
1.0
2.0
5.0
10.
20.8
Chinchilla 1441R
Percent cell loss
PTS (dB)
Hair Cells
Inner
Outer
PTS
Outer Hair Cells
1st Row
2nd Row
3rd Row
Pillar Cells
Inner
Outer
Percent total distance from apex